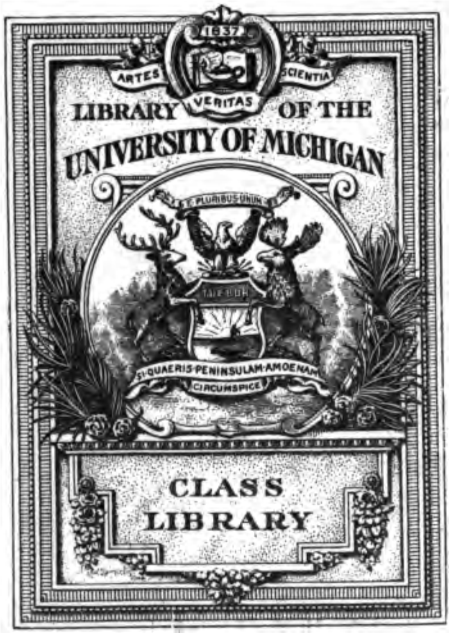
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**PROFESSOR I. P. ROBERTS,**
**Dean of Instructors in Cereal Crops, in an American Wheat Field.**

# The Cereals in America

BY

THOMAS F. HUNT

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# PREFACE.

As the title of this book suggests, the cereals have been treated principally with reference to their American environment, although valuable foreign data have often been included. This is especially true with reference to varieties, fertilization, culture, harvesting, production, use and marketing of these crops. It is not a monograph of experiment station literature. The limits of the work have made it impossible to include some valuable data. Moreover the author has deemed it his privilege to protect the reader by eliminating inconclusive and inconsequential data, which must of necessity accumulate in so large an enterprise as that represented by the various agencies for research in Agriculture. It is hoped, however, that the reader will find herein a fairly comprehensive, although concise, statement of experimental results as well as of farm methods relating to the cereals in America. Reference has usually been made to the station rather than to the individual for a number of reasons, the most important of which is that in the culture of these crops the location is frequently an important consideration. With few exceptions, the illustrations in this book have been drawn or re-drawn by C. W. Furlong or A. K. Dawson. The author wishes to express his grateful acknowledgment to those who have given him helpful suggestions, and especially to his secretary, Mr. C. C. Poindexter, B. S., O. S. U. 1903, for valuable assistance rendered.

TO INSTRUCTORS IN AGRONOMY:

The author recognizes the varying interest of the several States in crop production as well as the differences of curriculum and of facilities for instruction at the different agricultural colleges. He has tried to meet this rather wide requirement by a fairly full treatment of all the cereals, which will enable the Instructor to omit certain crops or certain portions of a particular crop. At the same time the collateral readings and copious page references to the original sources of information make it possible to enter into a more thorough study of any single crop or any special phase of that crop. The discussion of certain topics ordinarily not taught in the department of Agronomy has been put in smaller type for the benefit of the general reader. Cross reference is made to paragraphs in order to facilitate comparative study.

The method of treatment is in accordance with the recommendations of the Committee on Methods of Teaching Agriculture of the Association of American Agricultural Colleges and Experiment Stations.

In all courses of study involving the study of material objects it is important to recognize that the student should not only study about the thing, but he should study the thing itself. In Agronomy the importance of studying the crop in all its environments cannot be too strongly insisted upon. The ideal condition involves a study of the plant in the field. Unfortunately this is not always possible, since no systematic course of instruction can be planned that will conform with the season of crop growth and meet the exigencies of the weather. Practicums should be supplied that will as far as possible remedy this

defect. Neither the substance nor the form of the practicums here proposed is vital. The Instructor can modify them to suit his needs or plan others along similar lines. Here again the author has included more than any single course would probably offer, in order that the Instructor may choose such as he requires or as his facilities may permit. The author is aware that the success of his attempt to put this subject into pedagodic form is far from perfect. He will, therefore, be grateful to Instructors in Agronomy if they will submit to him any criticisms or suggestions that may occur to them either as to subject matter or method of treatment.

THOMAS F. HUNT.

CORNELL UNIVERSITY,
ITHACA, N. Y., October 1, 1904.

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# I.

## CLASSIFICATION AND CHOICE OF FIELD CROPS.

1. **Agriculture.**—The word agriculture comes from the two Latin words *ager*,[1] meaning field, and *cultura*, meaning cultivation. The strict meaning of the word is, therefore, the cultivation of the field. The sense in which the word is used, however, is quite varied. In its widest sense Agriculture consists in the production of plants and animals useful to man. It thus includes horticulture, forestry and animal husbandry. There are also certain manufacturing industries so closely and intimately connected with the production of the plants and animals that they are often included in agriculture, such as butter making, cheese making, sugar making, etc.

2. **Horticulture.**—The word horticulture comes from the two Latin words *hortus*, meaning enclosure, yard or garden, and *cultura*, meaning cultivation. Horticulture thus means the cultivation of the garden. The use of the word in this sense as well as the use of the word agriculture in the restricted sense of field agriculture is due to the character of Roman Husbandry during the time of the Roman Empire. The farm homestead in Roman agriculture was known as the "Villa." This farm steading was often an elaborate affair, including many buildings, and enclosures for the growth of fruits and vegetables. Outside the villa lay the extensive unenclosed areas on which were raised such crops as wheat, barley and some of the legumes. The tillage of unenclosed areas was known as agriculture, while the growth of the crops in the enclosed area was

[1] The word acre has the same derivation and originally meant a field of arable or pasture land. The acre was limited to its present definite quantity by statutes of Edward I, Edward III, and Henry VIII.

known as horticulture. In American agriculture, with the enclosure of all farm lands and large production of animals on these enclosed areas, on the one hand, and the extension of the growth of fruits and vegetables to large areas, on the other hand, these distinctions somewhat disappear. In general, horticulture consists in the production of fruits and vegetables.

3. **Agronomy.**—Comes from two Greek words meaning the use of the fields. Agronomy as here used is restricted to the theory and practice of the production of farm crops. The object in plant production is to adapt the environment to the anatomy and physiology of the plant under cultivation with a view to securing crops which are best suited to the uses of man or the domestic animals. A full understanding of the means of adapting the environment to the development of the plant requires not only a knowledge of the anatomy and physiology of plants, but it requires a knowledge of the air and soil and their means of modification. A study of plant physiology and a study of soils should, therefore, precede alike the study of either field or horticultural crops. Agronomy differs from botany in that botany deals with plants in the natural relationships and environments, while agronomy deals with man's relationship to plants.

4. **Field Crops.**—Under this head are generally included those crops that are cultivated on a somewhat extensive scale and are adapted to extensive rather than intensive methods of culture. There are exceptions to this rule. Sugar beets are classed with field crops, although the methods of culture are somewhat intensive, while all varieties of fruit are considered horticultural crops, although some kinds are now grown in large orchards and under conditions entirely removed from what was the case when the term horticulture was first applied.

5. **Number of Cultivated Species.**—De Candolle has recognized 198 species of cultivated plants native to the old world and forty-seven species of American origin, while there are

three of uncertain origin, making the total number of cultivated species 248.[1] He classifies the species as follows:

| | Old World | New World |
|---|---|---|
| Cultivated for the underground parts . | 26 | 6 |
| Cultivated for the stems or leaves . . | 57 | 8 |
| Cultivated for the flowers or their envelopes . . . . . . | 4 | 0 |
| Cultivated for their fruits . . . . . | 53 | 24 |
| Cultivated for their seeds . . . . . | 58 | 8 |
| Cryptogam cultivated for whole plant . | 0 | 1 |
| | 198 | 47 |

6. **Classification.**—No classification of the field crops of the United States can be made that will be entirely satisfactory and even if it could be made so, would not remain satisfactory, on account of new uses to which plants are constantly being put. The following classification will be used in this chapter, viz., cereals, grasses, legumes, tubers, roots, sugar plants, fibers, stimulants, medicinal and aromatic plants and miscellaneous crops. The following table shows the total area devoted to each of these classes of crops and their value as reported by census of 1900:

**Area and Value of Field Crops in 1899, in U. S.**

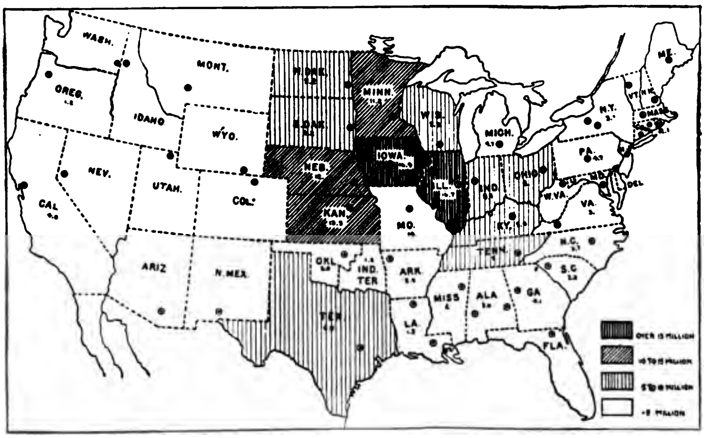
| | Area (acres) | Value of crops | Value per acre |
|---|---|---|---|
| Cereals . . . . . . . | 184,994,588 | $1,484,231,038 | $ 8.02 |
| Hay and forage[2] . . | 61,691,166 | 487,125,685 | 7.93 |
| Legumes for the seeds | 1,964,634 | 28,308,228 | 14.36 |
| Tubers . . . . . . . | 2,938,952 | 98,387,614 | 33.47 |
| Roots . . . . . . . | 537,447 | 19,876,200 | 36.98 |
| Sugar plants . . . . | 855,995 | 51,367,685 | 60.01 |
| Fibers . . . . . . . | 26,401,660 | 390,879,985 | 11.02 |
| Stimulants . . . . | 1,101,483 | 56,993,003 | 51.74 |

1 Origin of Cultivated Plants. By A. De Candolle, pp. 436-446.

2 Of the total area in hay and forage crops, 6.7 per cent was devoted to clover, 50.7 per cent to tame and cultivated grasses other than clover, 6.3 per cent to grains cut green for hay, 5.1 per cent to forage crops, 3.4 per cent to alfalfa, 2.8 per cent to millet and Hungarian grasses and 25.1 per cent to wild, salt and prairie grass.—Twelfth Census, Bul. 237, p. 14.

| | Area (acres) | Value of crops | Value per acre |
|---|---|---|---|
| Medicinal and aromatic plants . . . | 8,591 | $143,618 | $16.72 |
| Miscellaneous plants . | 234,197 | 7,670,343 | [1]32.79 |
| Total in field crops . | 280,728,713 | 2,624,983,399 | 9.16 |
| Total in vegetables and fruits . . . . . | 8,989,620 | 252,006,611 | 28.03 |

The total area in field and garden crops was approximately 290 million acres, while the total area of improved land was given at 415 million acres. This probably means that 125 million acres were in pasture. The area devoted to hay and pasture was therefore substantially the same as that given to the cereals. About one acre in thirty of the cultivated area was devoted to fruits and vegetables, while their value was about one-tenth that of the field crops.

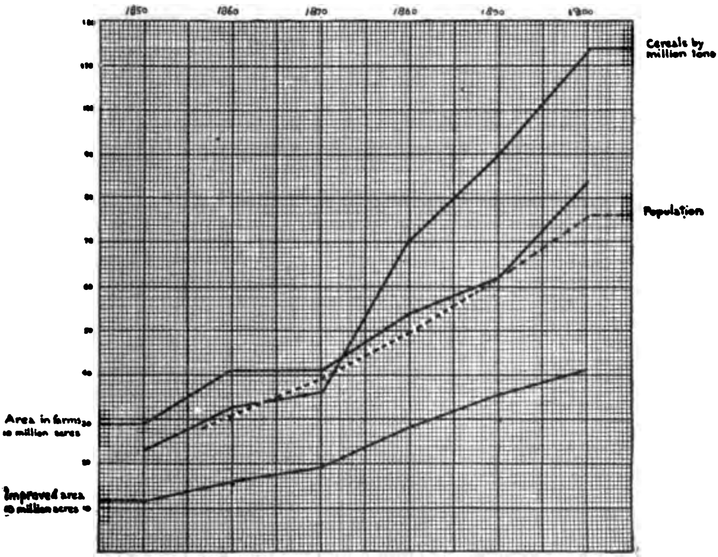


Acreage of cereals, Census, 1900.

7. **Cereals.**—Any grass grown for its edible grain is called a cereal. The term is applied both to the plant as a whole and to the grain itself. According to this definition, buckwheat is not a cereal. It is, however, generally so classed because the seed is used in the same manner as the true cereals.

[1] Refers to broom corn and hops.

The six great cereals of the world are wheat, rye, barley, maize, oats and rice. In addition to these the seed of the millet, or non-saccharine sorghum, is used largely by the peoples of southern Asia.




The relative increase in population and production of cereals during 50 years.

In all ages and in all countries the cereals have occupied the bulk of the cultivated area and have formed the principal ingredient in the dietary of the people, as well as forming an important part of the food of domestic animals. Rye is the leading cereal of northern Europe and barley of southern Europe, while rice is the leading cereal of Asia. In the United States the three just mentioned occupy a minor place, while maize, wheat and oats occupy by far the largest part of the cultivated area. The following table shows the proportion of the area of each cereal to all the cereals raised in the United States in 1899:[1]

1 Twelfth Census. Vol. VI, p. 14.

| | |
|---|---|
| Maize | 51.3 |
| Wheat | 28.4 |
| Oats | 16.0 |
| Barley | 2.4 |
| Rye | 1.1 |
| Buckwheat | 0.4 |
| Kafir corn | 0.2 |
| Rice | 0.2 |
| | 100.0 |

8. **Grasses.**—The area devoted to pasture, hay and forage crops in the United States is greater than that devoted to any other single crop, and the product is of greater value than any other. This, however, includes some of the legumes which are used for pasture, hay or forage.

There are about 3500 known species of true grasses, divided into about 300 genera. In the United States there are now known to be about 1380 species (1275 native and 105 introduced), divided among 165 genera (140 native and 25 introduced). W. J. Beal has described 809 native species and 103 exotic species.[1]

Lamson-Scribner gives the number of the best known and most valuable grasses for different purposes as follows: thirty-eight hay grasses, thirty-five pasture grasses, fourteen lawn grasses, twenty-four grasses for wet lands, twenty grasses for embankments, nineteen grasses for holding shifting sands. In a number of instances the same grass occurs in two or more different classes.

The principal cultivated grasses for hay are timothy and red top, the latter being especially adapted to wet lands, while Kentucky blue grass in the northern and Bermuda grass in the southern portions of the United States are the principal ones used for pastures and lawns.

9. **Legumes for Hay and Pasture.**—There are in the leguminous or pea family about 310 genera and about 5000 species.

[1] Grasses of North America Vol. II, 1896.

There are about 250 species in the genus *Trifolium* and about fifty species in the genus *Medicago:* the two genera to which most of the plants used for hay and pasture belong. The census for 1900 reports the total yield of alfalfa hay in the United States as slightly larger than that of clover hay from about one-half the area. The clover species commonly used for hay are common red clover, mammoth red clover, alsike clover and crimson clover, of which the first occupies much the largest area. The vetch is grown somewhat, principally in the Pacific Coast States. The cowpea has become an important forage crop in the Southern States.

All the legumes above mentioned are grown more or less for pasturage. In addition, white or Dutch clover in the North and Japan clover in the South are distinctively pasture crops.

10. **Legumes for Seeds.**—The principal legumes raised for their seeds are field beans, field peas, cowpeas and peanuts. The soy bean is also attracting some attention as a seed crop as well as a forage crop. New York and Michigan are the leading states for the production of field beans; Michigan and Wisconsin for field peas; Georgia and South Carolina for cowpeas, and Virginia, North Carolina, Georgia and Alabama for peanuts.

11. **Forage Crops.**—In its best signification the word "forage" means any kind of food for animals, whether hay, straw, grain, roots, etc. Often, however, it is used to apply to the whole plant or portions of plants other than the seeds, and thus to those foods containing a large proportion of cellulose or crude fiber.

In a more limited and technical sense a *forage crop* is an annual crop in which the whole plant is used for food. Thus maize is a cereal crop when the ears are husked and fed separately, while it is a forage crop when the whole plant is fed together either dried or ensilaged. Most of the plants used for forage are either grasses or legumes. Among the grasses the

principal forage crops are maize, sorghum or Kafir corn, millet, oats, barley: among the legumes are cowpeas and soy beans. The rape plant is used somewhat as a forage crop.

12. **Tubers.**—The only tuber of importance cultivated in the United States is the potato. Although the area devoted to the crop in this country is small compared to the total area under cultivation, yet the large yield of food per acre, the ease with which it is prepared for use, and the intensive character of the cultivation required, all conspire to make it an important crop. It is a relatively still more important crop in Europe, where the agriculture is more intensive.

The Jerusalem artichoke and chufa are also grown in a minor way for their tubers.

13. **Roots.**—Generally speaking, the climatic conditions do not favor the production of root crops in the United States. In Great Britain especially, turnips, ruta-bagas and the various forms of the beet are grown largely for stock food. These crops are quite as important there as maize is in the United States. Canada also raises root crops somewhat abundantly. The sweet potato is raised extensively in the southern part of the United States and is an important article of diet in that section. Chicory and cassava are minor crops.

14. **Sugar Plants.**—The principal sugar plants are the sugar cane and the sugar beet. At the present time the latter furnishes more of the sugar of the world than the former. In the United States the most sugar is produced from the cane. The area over which sugar cane can be raised is not believed to be large, while the area over which beets can be successfully grown for the production of sugar is believed to be much more considerable. It seems probable, therefore, that the production of sugar from the beet will continue to increase until much the larger part of the sugar will come from this plant. Sorghum is, also, grown for the production of syrup, and hard maple forests are maintained both for the production of sugar and syrup.

15. **Fiber Plants.**—The principal fiber plants of the United States are cotton, flax and hemp. In this country, however, flax is mostly grown for its seeds. The cotton plant is by far the most important fiber plant in the United States and is becoming increasingly the most important source of fiber either vegetable or animal in the world. Ramie, jute and sisal are also sources of fiber.

16. **Stimulants.**—Tobacco is of American origin and has been during the whole history of the United States an important industry and has constituted an important article of commerce. The tea plant is now being grown in a small way in South Carolina and, perhaps, elsewhere. Except in Porto Rico, Hawaii and other outlying possessions coffee has not been raised with commercial success.

17. **Medicinal and Aromatic Plants.**—Have not been cultivated largely. The following include the more important ones: mustard, mint (three species), tansy, pyrethrum (buhach), wormwood, valerian and ginseng.

18. **Miscellaneous Crops.**—Among the cultivated plants which are not included in the foregoing classification are broom corn, castor bean, hops, onions, teasel, taro, sunflower seeds, willows and pampa plumes.

19. **The Staple Crops of the United States.**—Are grass, including certain legumes, maize, wheat, oats and cotton. There has been a rapid increase in the cultivated acreage of the country and some changes in the proportion given to different crops, but there is little reason to believe that the time will soon come when these will not be the leading crops, at least so far as acreage is concerned. Almost every crop now grown on the farms of the United States had been grown to some extent before the Revolutionary War. Improvements in methods of culture, harvesting or in machinery for utilizing the crop have brought some crops into greater relative importance. This has been notice-

ably true of cotton and it is much to be hoped it may be true of sugar beets and alfalfa.

20. **Character of Field Crops.**—Prior to the discovery of America the field crops of Europe were almost all sown broadcast. In the United States at the present time, more than half the field crops are raised by intercultural tillage. Maize, the white potato and the sweet potato are of American origin, while cotton was not largely raised until the beginning of the nineteenth century. The method of harvesting is also quite different. What are usually known as the small grains have been harvested with the sickle, cradle, reaper and self-binding harvester in successive years and afterwards flailed or threshed, while the crops grown by intercultural tillage have been in the past mostly gathered by hand. Root crops, the sugar beet and potatoes have been added to European agriculture within comparatively recent times.

21. **The Beginnings of Plant Culture.**—The six great cereals of the world have been cultivated so long that the wild type of each can with difficulty be recognized. Of these, wheat, barley and rice have been cultivated for more than four thousand years, while the cultivation of maize, oats and rye has not been traced much more than two thousand years.

22. **The Possibility of Crop Production.**—Depends mainly on climate and soil. Of these the climate is the more important, especially when large areas are considered. Manuring, culture or drainage may greatly modify the soil and make it fit for crops for which it was illy prepared. There is, however, a marked variation in the adaptability of different soils under the same climatic conditions. Certain soils are much better adapted to wheat and grass than for maize and potatoes, while other soils are much better adapted to maize and potatoes. Tobacco is a crop that is readily affected by the character of the soil. Plants, like animals, have great adaptability: they may become acclimated and do fairly well when neither soil nor climate is like

their native land. Many wild plants show great vitality outside their original habitat. Many of our worst weeds are plants which have been removed from their original environment. Usually, however, it is unwise to attempt the growth of any crop which experience has shown to be illy adapted to the climate and soil of a given region: at least as a leading crop.

23. **The Profitableness of a Given Crop.**—Depends not only on the climate and soil, but very largely on the market facilities, and, so far as the individual farmer is concerned, largely on his tastes, experience and capital. The farming in many parts of this country has greatly changed not because of soil exhaustion or changes of climate, but because of changes in the market demands. Usually, in regions recently settled, where land is low-priced and transportation facilities are poor, farmers devote themselves to grazing cattle or sheep, or to the production of crops like maize and wheat or cotton, which can be readily transported long distances. Where the soil and climate are favorable wheat has been a favorite crop with new settlers, because a considerable acreage can be grown with comparatively little expenditure of money or labor, and a money return can be secured more quickly than if stock raising be selected as the chief business. As the land advances in value, especially near large cities, the production of crops which give a larger money return for the acreage and of such as cannot be carried great distances without injury becomes more common.

24. **The Choice of Crops.**—The general practice is usually the safest guide. There are many exceptions to this, but no safer rule can be given to one about commencing farming in a region with which he has little acquaintance than to follow the practice of the most successful farmers in the vicinity, at least in the beginning of his work. On the other hand, it not infrequently happens that the most profitable farming in a community is that by some one who has introduced a new industry or sought to give a home supply of some article which has been

brought from a distance. A man of special skill and intelligence may sometimes wisely work against peculiarities of climate and soil. It often happens that those who are first to see the probable value of a crop new to the region, or first to adapt their farming to changing conditions, are much more successful than their neighbors.

25. **Specialties.** — A wisely selected specialty often gives much larger profits than come to the farmer who divides his efforts among several branches of farming. The specialty farmer ought to learn more about producing and disposing of his one crop than if he looked after several. He has a better opportunity of making a good reputation and of getting somewhat higher prices. He may be able to produce more cheaply by better use of machinery. Specialties which require most of intelligence and skill may give largest profits, with possibilities of large losses.

26. **General Farming.**—For most farmers the production of several crops is safer and wiser than giving nearly exclusive attention to one crop. It usually enables the farmer to distribute his labor and that of his employes and teams to better advantage throughout the year. It gives the advantages of a rotation of crops and, if stock feeding is a part of the system, of retaining much of the manurial value of the crops on the farm. It is something of a safeguard against poor yields and poor prices. It rarely happens that all the crops give poor yields, and also bring low prices. The attempt to produce a little of each of a large variety of crops on any farm is almost always unwise. The safe rule is to give the chief attention to one or two or three crops, but not limit the crops to these.

## Practicum.

27. RELATIVE IMPORTANCE OF FIELD CROPS.—Give each student an outline map of the United States such as prepared by the U. S. Weather Bureau. Require each to indicate by suitable legend the percentage of area in cereals, hay and forage, and fiber crops to total farm area in each State. The data may be obtained from census reports or the reports of the U. S. Department of Agriculture.

28. COLLATERAL READING.—Corn Plants. Their Uses and Ways of Life. By F. L. Sargent. Boston: Houghton, Mifflin & Co., 1902.

Twelfth Census of the United States. Vol. VI.

Twelfth Census of the United States. Bul. 237.

Origin of Cultivated Plants. By Alphonse De Candolle. pp. 447-462. New York: D. Appleton & Co., 1902.

# II.

## IMPROVEMENT OF FIELD CROPS.

29. **Changes in Farm Crops.**—Probably there is no grain, grass, fiber or root crop cultivated in the United States which has not been greatly changed since it was a wild plant. In recent years many new varieties have been produced, differing in marked degrees from those formerly cultivated. Farmers generally do not actively interest themselves in the improvement of their crops; are not always careful to maintain them in their present standard of excellence. Much less attention has been given to the improvement of farm crops than to the improvement of farm animals.

30. **The Importance of Plant Breeding.**—The individual plant is the result of two forces: environment (climate, soil, fertilizer, culture, etc.) and heredity (parents, grandparents, etc.). The increased yield of a crop by modification of environment, although a necessary process to successful agriculture, can only be accomplished by an expense more or less considerable. Heredity, however, is a silent force, which acts without expense. If a plant be discovered that would produce because of the force of inheritance only one grain of maize more on each ear than at present, it would be capable of increasing the maize crop of the United States five million bushels of maize, not next year alone but for years to come. This is the significance of improved seed.

"The vast possibilities of plant breeding can hardly be estimated. It would not be difficult for one man to breed a new rye, wheat, barley, oats or rice which would produce one grain more to each head, or a corn which would produce an extra kernel to each ear, another potato in each plant, or an apple, plum, orange or nut to each tree. What would be the result? In five staples only in the United States alone the inexhaustible forces of Nature would produce annually without effort and without cost:

5,200,000 extra bushels of corn,
15,000,000 extra bushels of wheat,
20,000,000 extra bushels of oats,
1,500,000 extra bushels of barley,
21,000,000 extra bushels of potatoes.

"But these vast possibilities are not alone for one year, or for our own time or race, but are beneficent legacies for every man, woman or child who shall ever inhabit the earth. And who can estimate the elevating and refining influences and moral value of flowers with all their graceful forms and bewitching shades and combinations for color and exquisitely varied perfumes? These silent influences are unconsciously felt even by those who do not appreciate them consciously, and thus with better and still better fruits, nuts, grains and flowers will the earth be transformed and man's thoughts turned from the base destructive forces into the nobler productive ones, which will lift him to higher planes of action towards that happy day when man shall offer his brother man not bullets and bayonets, but richer grains, better fruits and fairer flowers.

"Cultivation and care may help plants to do better work temporarily, but by breeding, plants may be brought into existence which will do better work always, in all places and for all time. Plants are to be produced which will perform their appointed work better, quicker and with the utmost precision."[1]

31. **A Maize Breeding Farm.**—A company in Illinois has a tract of 27,000 acres upon which they propose, if possible, so to breed the standard varieties of maize as to give the greatest feeding value per acre. They propose to breed maize with varying per cents of fat or protein as seems possible by the experiments of the Illinois Station.[2] If a company had proposed to breed Holstein-Friesians whose milk should contain a high per cent of butter fat it would not be considered remarkable, yet the definite breeding of farm crops is so unusual as to create great interest in this new enterprise. The fundamental principles in breeding are the same whether applied to plants or animals. The study of the principles of breeding especially as they apply to animals is a recognized part of courses in agriculture. No attempt will be made in this chapter to discuss these principles but merely to point out some of the practical applications to plant breeding.

32. **Application of Principle Delayed in Plants.**—A number of circumstances have prevented the application of the prin-

[1] Luther Burbank.

[2] In referring to the Agricultural Experiment Stations under government and state control the word "Station" only will be used for the purpose of brevity.

ciples of breeding to plants, although they have been applied to the breeding of animals for many years. Among the circumstances are the following:

1. Lack of knowledge of the sexuality of plants until recent times.

2. Difficulty of control in breeding plants.

3. The selection is made from seeds which are embryos and not mature individuals.

The last two circumstances apply much more to some plants than to others. They apply with special force to ordinary field crops.

33. **Sex.**—The sexes in animals must have been known from the earliest times. Camerarius first published experimental proof of the sexuality of plants December 28, 1691. It was not until after this discovery that the function of pollen and its necessity to seed formation was understood. It will be readily appreciated that this knowledge did not become general among the growers of the staple crops until much more recent times and is perhaps still not understood by many. Thus there has been more or less systematic breeding of animals for 4000 years, while the mating of plants has not been practiced for more than two hundred years.

34. **The Difficulty of Control in Breeding Plants.**—The pollen of plants cannot ordinarily be confined, while the male domestic animal can be tied up by a halter or confined in a yard. In some plants like maize which is wind-fertilized we have no knowledge of the plant from which the pollen came and consequently no knowledge of the characteristics of the sire. In other plants like wheat that are self-fertilized two individuals cannot be mated without resorting to artificial means.

35. **The Seed an Embryo.**—The selection is usually made from the seeds. The seed is an embryo, not a mature individual. The characteristics of the mature chicken cannot be fully foretold by looking at the egg. The seed must be grown

and the plant observed through youth, maturity and old age before the characteristics of the individual plant are fully known. The individual animals are constantly under the eye of the successful breeder. The poorer animals are rejected and only the better animals mated. In the case of plants there is not only usually no mating, but the mature individual from which the embryo is obtained for the subsequent progeny is unknown. This is not quite so true of maize as of the other cereals, because of the method of harvesting the crop. Even if the large ear of maize is a measure of the productiveness of the individual maize plant, the character of the sire is unknown. In the case of the other cereals, or of potatoes, the size of the grain or tuber is no necessary measure of the productiveness of the parent. A small grain from a fine, well-bred individual is better than a large grain from a poor, indifferently-bred individual. Other things equal, a small tuber from a large hill of potatoes is better than a large tuber from a small hill. In case the large and small seeds come from equally good heads of wheat, which will probably be the case under average conditions, the large seeds may perhaps give the best results, especially as under field conditions the larger size may be of advantage in enabling the plant to get a more vigorous start. Specific proof of this is, however, lacking. Hays believes it to be established that the best heads of wheat, as well as best plants, should be selected. In the case of maize the butt and tip grains have been found to be substantially equal to the middle grains of the ear. (272) To succeed in plant breeding the seed must be selected from individuals which possess the characteristics it is desired to perpetuate.

**36. Examples of Improvement or Modification in Plants.**—Many of the modifications which have taken place in plants during cultivation by man may be said to be unconscious. At least there was no definite plan to accomplish the results attained.

A good illustration of unconscious improvement is to be found in cabbage, kale, collard, palm borecale, Brussels sprouts, kohl-rabi, ruta-baga and cauliflower. These all come from a single, somewhat woody, branching perennial (*Brassica oleracea L.*) which is to be found growing wild on limestone bluffs in southwestern Europe. Some are a modification of the leaf, as in the cabbage and kale, others of the stem, as kohl-rabi, still others of the root, as ruta-baga, while in the cauliflower it is the selection of the inflorescence that has caused the peculiar modification. Some of these types have twenty or thirty varieties, so that there are probably over one hundred distinct forms from this one wild type. All of these forms are the result of long and patient selection of variations that were considered desirable by the gardener without any conscious attempt to produce these specific forms.

37. **Examples of Definite Improvement.**—The sugar beet is an illustration of systematic breeding to bring about a definite improvement. In less than a hundred years of systematic selection of individuals of known excellence, and by testing their ability to reproduce the desired characters, the common garden beet, with 6 per cent of sugar, has been transformed into the sugar beet, which often contains from 15 to 20 per cent of sugar and is otherwise improved.

By similar methods, wheat, flax, timothy and other farm crops are being systematically bred for definite characters. The proper method to be employed will be discussed under the crop in question. Much greater advance has been made with vegetables and other horticultural crops than with field crops.

"At the present day species that have been cultivated for many years have become, so to say, like wax in the hands of special growers, who mold them and fashion them to their taste, obtaining the various modifications of shape, size, flavor, etc., demanded by their patrons and the caprices of fashion."[1]

The time will doubtless come when there will be many breeders of pure strains of maize, wheat, timothy and other field

[1] Henry L. De Vilmorin. E. S. R., Vol. XI, p. 6.

crops, just as there now are many breeders of pure strains of domestic animals.

38. **Methods of Improvement.** — There are three steps or methods in the improvement of plants or animals, viz.:

A. Inducing variation.

B. Selection of forms having desired characteristics.

C. Testing the power of specific forms to reproduce themselves.

39. **A. Inducing Variation.**—Variation is the basis of selection. Plants must vary or they could not be selected. There are two general methods of producing variations, viz.:

1. Environment, such as soil, climate, space, cultivation, etc.
2. Crossing.

40. **The Influence of Environment.**—The causes of variability cannot be discussed here, but the following facts should guide the breeders of plants.

1. Horticulturists do take advantage of a superabundance of food in causing modification or multiplication of parts, such as the development of petals from stamens. After this habit becomes fixed it will be transmitted in some measure even in poor soil.

2. Nevertheless the most important value of cultivation in the case of most plants is to allow the plant breeder or cultivator to study individual forms. It enables him to select the desirable forms and reject the undesirable ones. By milking the cow and testing her milk we are able to select the best milkers. By trotting horses we are enabled to breed those best able to trot. Whatever influence milking or trotting may have, the fact remains that it makes possible intelligent selection.

3. The variations selected should be those induced under the environment in which we expect to continue to grow the crop. If we expect to grow three stalks of maize to the hill in general field culture, it is desirable to select the ears for planting from maize grown in a similar manner, rather than from ears

where but one stalk is grown in a hill. In the latter case the size of the ear will not be a criterion of the size of the ear where three stalks are grown in a hill. Where it is not possible to make selection under field conditions, care should be taken to select from among plants under like environment and subsequently subject to field conditions.

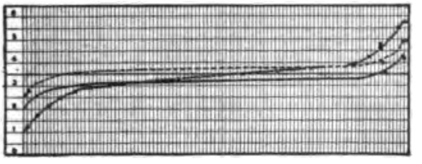
"In selecting sugar beets," says Vilmorin,[1] "those roots are sought for that are straight, long, and free from lateral branches. This is right, for those that are branched are more difficult, and hence more expensive, to gather. Now, certain growers of beet seed in the north of France once formed the idea—thinking, no doubt, in this way to improve their varieties—of growing the plants which were to be used as seed stocks in very rich deeply worked soil where they were very much crowded together; so much so that 16 to 20, or even more, grew on one square meter of ground. The result was that the beet assumed the form, and later the length of a whipstock. They were not branched because the roots were very closely crowded together. Their sugar content was abnormally high as a result of their growing so close together, and the conclusions drawn from the form of the roots and their sugar content, as determined in the laboratory, were tainted with error because they did not represent qualities truly acquired, but modifications accidentally imposed by external conditions. Thus these beets which were declared to be of good shape and composition in the laboratory yielded seed which when sown in the open field, produced branched roots of only moderate sugar content, because the descendants had reassumed their true characters when they were released from the restraint which had been artificially imposed upon the parent plants."

41. **Change of Seed.**—A frequent change of seed is not necessarily a good thing; certainly it is not necessary to obtain seed from distant parts of the country for a region whose soil and climate are well suited to the crop. If the region is not well adapted to the crop frequent new supplies of seed may be helpful and even essential. Probably no part of the world is better adapted to maize than is much of the central Mississippi valley. There would seem to be no good reason for changing seed of maize in this region. Much of this same region is not equally well suited for the oat crop. The climate is too hot and dry. The oats are much lighter than those produced in more moist and cool regions. Obtaining seed oats from regions where the crop does better may be good business management.

[1] E. S. R., Vol. XI, p. 13.

42. **Crossing.**—Crossing two unlike forms or two varieties may not be a fundamental cause of variation. Some other cause must have operated to have produced the two unlike forms. In practice, however, crossing is a means of inducing variation, so as to enable the breeder to select forms more nearly suited to his ideal. This is shown by Hays[1] in the case of a hybrid between Fife and Blue Stem wheat.

Some of the plants of hybrid wheat yielded more and some less than any of the plants of either the Fife or of the Blue Stem. If the yield is the characteristic desired, then a few plants of the hybrid were better than either of the present varieties.



Influence of crossing as a cause of variation.

Yield in grains of 100 plants, showing greater variation in yield of hybrid wheat than of either parent form. The yield of the hybrid is indicated by the line marked —x— (After Hays.)

Crossing is also employed not only to induce variation but to combine two or more desirable qualities in one plant.

43. **B. Selection.**—Plants having varied either through the efforts of the breeder or otherwise, the next step is to select plants having the characteristics desired. "Selection is the surest and most powerful instrument that man possesses for the modification of living organisms."[2]

The unit of selection is the individual. In the case of wheat the unit is not the seed, nor even the head of the wheat, but it is the stool containing several heads and many seeds which have been produced from a single seed. In the case of the potato it is the single hill and not the single potato. However, in plants, unlike higher animals, portions may be used for the purpose of

[1] Willet M. Hays. Plant Breeding. Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, Bul. 29, p. 21.

[2] Henry L. De Vilmorin. E. S. R., Vol. XI, p. 19.

reproduction and the inheritance of variations in these parts is recognized as possible.

Only useful characters should be selected, because two characters are more difficult to develop than one; three more difficult than two, and so on. Some characters are mutually antagonistic, as extreme earliness and either great size or productiveness. To select wisely requires deep study and good judgment. Varieties frequently deteriorate on account of unwise selection. This is especially true of maize, although it is the field crop which it is the easiest to select.

44. **C. Testing Power of Specific Forms to Reproduce Themselves.**—Having selected a desired form, it is next necessary to test its ability to transmit its characters. Even though the sire (plant furnishing the pollen) may be known, there is no certainty that the plant will transmit the characters which it possesses. Different grains from the same head of wheat are known to yield unequally. Some variations are easily fixed: others require generations of selection before the characters can be depended upon. Under ordinary farm conditions the ability of individuals to reproduce themselves is not tested, and furnishes a very important reason why little progress has been made in the improvement of field crops. Take timothy, for example. A casual inspection of a field of timothy will show that there is a great variation in the length of head, the length of stem, the amount of leaves and number of stalks per stool. Under the usual method no selection is exercised, and no test of the power of the transmission of characters is possible. A few experimenters have selected plants (stools) having different characteristics and by planting 100 seeds from each plant in rows, one seed at a place, have obtained remarkable results. After the ability of the plant to transmit its characters has been demonstrated, the seed can be rapidly multiplied for field purposes.

It is well understood by livestock breeders that the best individual does not always produce the best progeny. It is a

common expression that this animal is a good breeder or that animal a poor breeder.

At the Ohio State University in 1902, fourteen ears of maize of a given variety were selected, and two rows of fifty hills each were planted from each ear. The smallest ear, containing next to the smallest weight of maize, produced the heaviest yield of maize. This ear weighed 14 per cent less than the average weight of the fourteen ears and yielded 32 per cent more than the average yield of the same fourteen ears. This testing of the power of plants to transmit their characteristics is painstaking work, and will form a large part of the work of the successful plant breeder.

45. **Importance of Large Numbers.**—If a thousand persons stand in a row it will be found that most of them are nearly the height of the average, while a few are considerably shorter and a few considerably taller than the average. The length or weight of a number of ears of maize will vary in the same manner as shown in wheat. (42) In fact this seems to be a universal law of organic beings. Most of them tend to breed true to type: a few vary considerably from the type. In order, therefore, to make progress in breeding it is necessary to find the organisms that have the tendency to vary as desired. Among a million organisms there may be only one that possesses the required characteristics. The chances of finding the desired individual increase as we increase the number from which selection is made. The chances of securing satisfactory results are increased many fold if 5000 seeds are planted instead of 500.

46. **The Plant Breeder's Advantage.**—It has been shown that the breeder of animals has the advantage of the breeder of plants in that he can more easily control the mating of the parents. The breeder of plants has a distinct advantage in being able to work with large numbers.

In the case of livestock only the inferior females can be discarded, because in working with adults the expense of discarding

the adults cannot be afforded. Indeed the number of sires that are to be found in the upper end of the curve is so small that the sires are apt to be but little if any better than the average. In the breeding of animals in practice it is the few inferior animals represented by the lower end of the curve that are discarded. In the case of plants, however, embryo plants (seeds) are produced in such abundance and at so small expense that only the few at the upper end of the curve which are distinctly superior need be saved. Instead of discarding the poorest ten per cent, as in the case of animals, only the best five, or even one, per cent may be saved in the case of plants.

## Practicums.

47. To Demonstrate the Law of Variation from Type.—Take one hundred ears of maize of one variety. Take weight of each ear in grams, or ounces, and mark with gum label. Arrange ears in order of weight. Furnish each student with a sheet of cross section paper, five inches square, with twenty sections to the inch, or five by ten inches, ten sections to the inch, and have each plot the curve indicated by the weight of the hundred ears. If necessary to save time, the instructor may have ears weighed and marked in advance of the class exercise. Variations in the length of one hundred ears may be shown in the same way.

Variation in the weight of grains of wheat may be shown if facilities for accurate weighing are at hand. The larger the number of grains used the better.

48. Organs of Reproduction.—In order to become familiar with the floral parts of wheat and other cereals, furnish each student with several heads of wheat in different stages of inflorescence:

1. Describe ovulary and state changes in size at different stages of maturity.

2. Describe stigmas, state number of styles and position at various stages of maturity.

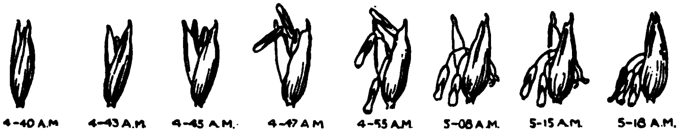
3. Describe length and position of filaments at different stages of maturity and note manner and mode of attachment of filament to anther.

4. Describe method by which anthers open and discharge their pollen. Describe the pollen grain.

For a portion of this work a high power microscope will be desirable. A two-inch, two-thirds-inch and one-sixth objectives will be found suitable. With a large class specimens may be prepared by the instructor and placed under one or more microscopes and each student allowed to make examination by turn.

To show that rye is cross-fertilized, while wheat is generally self-fertilized, a similar study of rye may be made. The large anthers and abundant pollen of the rye will be found to be the most striking contrast.

49. Time and Manner of Blooming. — The student may be required to watch the opening of the wheat flower and the discharge of the pollen. Hays has shown that this whole process may take place in less than an hour in spring wheat and that it usually occurs in the early morning hours.




The opening of wheat flowers. (After Hays.)

50. Collateral Reading.—Selection and Its Effect on Cultivated Plants. Henry L. De Vilmorin. Experiment Station Record, Vol. XI, pp. 3-19.

Plant Breeding. Willet M. Hays. Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, Bul. 29, pp. 7-24.

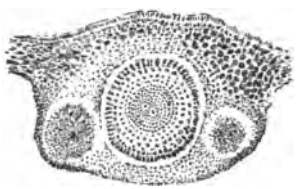
The Station for Plant Breeding at Svalöf, Sweden. By David G. Fairchild. Experiment Station Record, Vol. XIII, pp. 814-819.

# III.

## WHEAT.

### I. STRUCTURE.

51. **Relationships.**—Wheat belongs to the family of true grasses (*Gramineae*). The *Gramineae* are characterized by having hollow stems with closed joints, alternate leaves with their sheaths split open on the side opposite the blade. Wheat is included under the tribe *Hordeae*, in which the spikelets are one to many-flowered, sessile and alternate, thus forming a spike. (59) To this tribe belong also rye and barley, as well as the cultivated rye grasses (*Lolium perenne* L. and *L. italicum* Beauv.). This tribe also includes some troublesome weeds. Couch grass (*Agropyron repens* Beauv.), a perennial, was formerly included in the same genus as wheat. Because of its underground stems, or rhizomes, couch grass is difficult to eradicate and thus becomes a very troublesome weed in cultivated fields. Darnel (*Lolium temulentum* L.) is common in wheat fields in Europe and on the Pacific coast in this country. A related species (*L. remotum*) occurs in flax fields.



Cross section of a grain of wheat through embryo showing tips of three rootlets before germination. (From microphotograph by Rowlee.)

52. **Roots.**—When a grain of wheat germinates, it throws out a whorl of three seminal or temporary roots. The coronal or permanent roots are thrown out in whorls from the nodes. The distance between the temporary roots and the first whorl of permanent roots will depend somewhat upon the nature of the soil, but principally upon the depth of planting. The depth at which the first whorl of permanent roots occurs will vary with the

soil, but is usually about an inch from the surface, irrespective of the depth of the grain or of the temporary roots. There is nothing in the nature of a tap root in any of the grasses such as is found in the legumes. Any node under the soil, or even near the soil, may throw out a whorl of roots. When wheat is planted under ordinary field conditions the roots curve slightly outward and then descend almost vertically. The more unoccupied soil about a wheat plant the more the roots curve outward. As soon as the available surface soil is occupied the roots descend. An abundance of roots has been observed at a depth of four feet, and under favorable conditions they doubtless go much deeper. Schubart traced the roots of a winter wheat plant seven feet deep.[1] Webber found that if the roots of one wheat plant were placed end to end they would reach 1,704 feet.[2] Near the surface the roots branch and re-branch abundantly, filling the soil with a mass of roots, the ends of which are covered with root hairs. The Minnesota Station found about eight branch roots to the inch on the main roots to a depth of eighteen to twenty inches, varying in length from one-half inch to twenty inches. Below this distance few or no branches were found, suggesting that the purpose of these deep roots was to secure water.[3]

53. **Culms.**—Like the majority of the plants of the grass family, wheat has usually hollow culms, but in some varieties this space is more or less filled with pith. The greatest variation is found in the upper internode, which should be examined in describing a variety. The walls of the culm also vary in thickness, and the surface varies in color, and may be whitish, yellow, purple or brownish. Just below the spike the surface of the culm is more or less furrowed. The length varies with type and variety. The same variety is variable on different soils, with different fertilizers, and in different seasons. The variation in length of stem and yield of straw is greater than in size or yield

[1] Agricultural Botany. M. C. Potter. p. 170.

[2] Ibid.

[3] Minn. Bul. 62 (1899), p. 405.

of grain. It would not appear that there is any necessary relation between the length of straw and the yield of grain, although, all other things equal, the longer the culm, the greater the yield of grain. The club varieties of wheat grow about two feet high, while common wheat varieties grow to a height of from three to five feet; probably the average height is four feet.

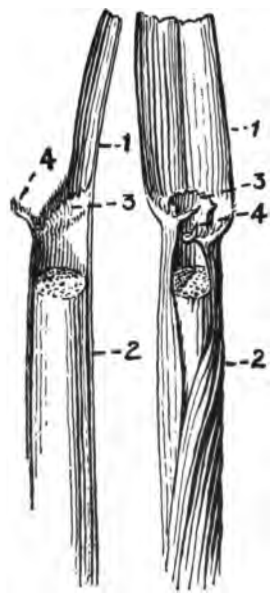
The length of the culm has an important influence upon the liability to lodge, and also influences the ease of harvesting. It seems probable that the yield of straw may affect the loss in soil fertility, especially if the straw is not returned to the soil. On land of good average fertility the Ohio Station produced ninety-five pounds of straw for each bushel of wheat during a period of ten years' continuous culture without fertilizers; 115 pounds per bushel where a complete commercial fertilizer was used, and 111 pounds per bushel where farm yard manure was used annually.[1]

During the early growth of wheat the nodes are very close together and consequently the plant consists principally of leaves. This condition obtains until the wheat begins to shoot, which consists of the lengthening of the internodes and the pushing up of the spike. The leaves which were formerly bunched together within a foot of the surface of the ground are now scattered along the culm, and in field conditions are comparatively scanty, and apparently inactive, except near the top of the culm, even at the time of blossoming. As the weight of the starch, as well as other material laid up in the seed subsequent to this time, is large, and as no starch is found laid up in the leaves prior to this time, as in some other plants, the question has been raised as to the ability of the active leaves to elaborate so much starch in so short a time. In fact, during the latter part of the ripening period only the glumes and the upper part of the stem remain green. Investigations indicate that the glumes do not have the capacity to form carbohydrates from the air, while the upper part of the stem has such power.[2]

1 Ohio Bul. 110, p. 47.

2 Ann. Agron. 28 (1902), No. 10, pp. 522-527. (E. S. R., Vol. XIV, p. 634.)

54. **Leaves.** — There are four parts of the wheat leaf that should be distinguished: (1) the blade, which may vary in length and width, in shape, in smoothness, and in the prominence of its veins; (2) the sheath, which, as in all plants of the family, clasps the stem tightly and is split down the side opposite the blade; varies in growing plant from green to purple; (3) the ligule, a thin, transparent tissue borne at the juncture of the blade and sheath and clasping the culm, varying in length from .07 to .1 of an inch (1.7 to 2.5 mm.[1]); and (4) the leaf auricle, thin projections of tissue, outgrowths from the base of the leaf blade varying in color and hairiness.



A wheat leaf, showing 1, blade, 2, sheath, 3, ligule, and 4, auricle. (About natural size.)

55. **Tillering.**—Inasmuch as buds form in the axis of the leaves, by covering with earth, both roots and culms (branches) will form at any node upon the culm. Ordinarily, however, branches form only at the lower nodes. The number of branches which can form from a single culm is necessarily limited, but each branch may produce a limited number of branches and these branches in turn other branches, so that under favorable conditions several dozen culms and consequently spikes may be produced from a single seed. This is known as tillering and is one of nature's methods of giving the plant power to adapt itself to its environment. Under ordinary field conditions only a comparatively few culms form, but

[1] The Description of Wheat Varieties. By Carl S. Scofield. U. S. Dept. of Agr., Bureau of Plant Ind. Bul. 47, p. 12.

at least fifty-two spikes have been produced from a single seed.

The "stand" of wheat may be materially affected by the amount of tillering, and, therefore, a study of those conditions which will promote tillering is advisable. On the other hand, it is probable that the best yields are not obtained where too much tillering is encouraged through thin seeding.

"In starting from the seed the stem soon begins to branch. The first leaves which are sent up seem to be a temporary set of organs designed to quickly reach above the soil, that the plant may be supplied with green cells in the sunlight. These leaves form what appears to be the primary shoot of the plant, and spring from the stem near the seed. They are found to be dead in the spring, along with the germ whorl of roots, in case of several varieties of winter wheat. At the same point where these first leaves arise another stem, apparently a rhizome, branches off from the primary stem. This rhizome has an internode quite unlike all the other lower internodes, not even covered by the sheath of a leaf, and extending about half way to the surface of the soil. In case the seed is planted two inches deep this rhizome is about one inch long. At the top of this internode a joint bears a leaf, and a few other joints follow at very short intervals, each having a bud in the axil of its leaf."[2]

A stool of wheat.
Culms are from a single seed originally at *a*. One-third natural size.

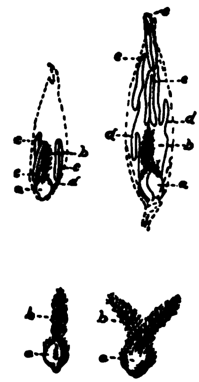
**56. The Organs of Reproduction.**—The flower of the wheat plant has three stamens. The anthers are attached to the tapering end of the thread-like filaments below the middle. As the flower opens the filaments rapidly elongate, pushing up and outside of the glumes the anthers which previously were closely packed about the ovulary.[3] The attachment of the filament to the anther is such that the anther suddenly upsets and the pollen falls out of

1 Neb. Bul. 32, p. 91.

2 Minn. Bul. 62 (1899), p. 407.

3 NOTE: The word ovulary is here used in its proper sense, instead of the term ovary which is so often incorrectly used.

the slits which are formed in the upper end of the two compartments. This process takes place apparently in a very short space of time. (49) The ovulary is one-seeded and is surmounted by two feathery stigmas which prior to the opening of the flower are erect and adjacent. As the flower opens the stigmas fall apart to receive the pollen. Pollination being effected, the stigmas soon wither and the ovulary rapidly enlarges. The development of the ovule (seed) from the period of flowering to maturity is very rapid and emphasizes the importance of proper soil and climatic conditions at that time. (49)

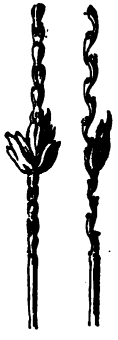


Organs of reproduction in wheat: *a*, ovulary; *b*, styles and stigmas; *c*, anthers; *d*, filaments of stamens. Upper left illustration shows flower before opening; upper right illustration shows flower about to open and protrude anthers. (After Hays.)

57. **The True Flower.** — The ovulary, stigma and stamens are enclosed within two chaffy parts, the inner of which is called a palea and the outer and lower the flowering glume. These parts collectively constitute the flower of the wheat. The awn or beard is borne on the flowering glume and varies greatly in length in different varieties or even in the same spike, or may be entirely wanting. In some varieties the awns are deciduous or partly so upon ripening. They vary in color from very light yellow to black.

58. **The Spikelet.**—Two to five flowers are enclosed within two chaffy and still harder parts called empty or outer glumes. This is called collectively a spikelet. There is considerable variation in the number of flowers maturing seed, due to variety and environment. In the varieties of common wheat there are generally three or more flowers in each spikelet, which usually matures two or three grains,—more commonly two. The outer glumes differ from those in rye by being oval rather than awl-

shaped. They vary considerably with variety and thereby furnish means of distinguishing varieties. They may vary in color from light yellow to black, uniformly or in streaks, may be smooth or hairy (sometimes called velvety), may vary in shape and length. The keel varies in width and distinctness and its tip or beak in length and sharpness. The shoulder, which is that portion of the glume on either side of the keel, and its tip (auricle) vary in width and shape and the notch between the auricle and the keel varies in depth or may be wanting. The apical glumes, i. e., the outer glumes of the apical spikelet, vary from the other outer glumes and should be separately described.


Front and side view of spikelet, showing mode of attachment to rachis.

59. **The Spike.**—These spikelets in the grass family are arranged in two ways, viz., on a more or less lengthened branch or rachilla, as in the oat, when the whole head is called a panicle; or joined directly to the stem (i. e., by a very short rachilla), as in wheat, rye and barley, when the head is called a spike. (51) In wheat, rye and barley, as in several other species of the grass family, the spikelets are arranged alternately at the joints of the zigzag jointed stem or rachis, the stem being excavated on the side next the spikelet. In the wheat genus (*Triticum* L.) there is but one spikelet at each joint and it is placed flatwise, usually on a single spike. There is usually borne on the rachis at the base of each spikelet a growth of short bristly hairs, to which Scofield has given the name of basal hairs.[1] These may be either white or brown in color and may vary in length or be wanting. Often in the cultivated varieties and always in the wild species, the lower one to four spikelets are sterile. The empty glumes are somewhat broader than the flowering glumes. The number of spikelets in a spike

[1] U. S. Dept. of Agr., Bureau of Plant Ind. Bul. 47, p. 14.

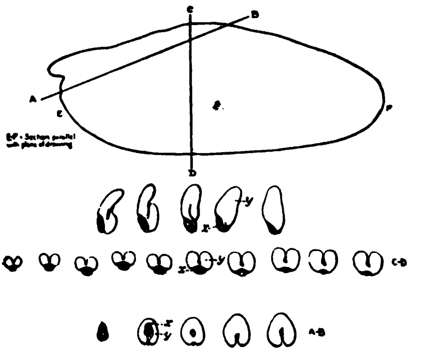
varies widely with the variety, soil, climate and culture. In this country a good spike of wheat will usually contain from fifteen to twenty fertile spikelets and contain from thirty to fifty grains. There is a marked difference between the length of the spikes of English and American grown wheats. In the United States the length of the spike varies from three to four and a half inches, a common length being three and three-fourths inches. Hallet has reported raising a spike of wheat eight and three-fourths inches long and containing 123 grains produced by five years of selection and favorable environment from a spike four and three-eighths inches long and containing forty-seven grains. Investigations by Lyon seem to show no relation between average weight of grain and the number on the spike.

The yield of wheat is affected by four factors, viz., (1) the number of spikes per a given area, (2) the number of spikelets in a given spike, (3) the number of grains in a spikelet, and (4) the weight of the grain. While there is no probability that such results as were reported by Hallet can be obtained in this country, it seems that the most hopeful method of increasing the yield is by increasing the number of spikelets in a spike.

The spike varies in compactness and in form. When viewed sidewise it may be straight or curved; may taper toward apex, both ways or have uniform sides, or may be clubbed at the upper end. The tip may be acute on account of undeveloped spikelets or blunt because they are well filled. The base of the spike may be tapering or abrupt for similar reasons. When viewed endwise the spike may be square, flattened with spikelets or flattened across spikelets.

60. **The Grain.**—The wheat grain is a unilocular, dry, indehiscent fruit called a caryopsis, with a thin membranous pericarp adnate to the seed, so that pod and seed are incorporated in one body. The grain is longer than broad, hairy at the apex, slightly compressed laterally, has a deep furrow on

the side opposite the embryo, causing a deep infolding of the pericarp or bran, which makes the roller process of milling a superior method. It is characterized by a small embryo, and a large development of endosperm from which the flour is obtained. Bessey estimates the cubic contents of a wheat grain to be from twenty to thirty cubic millimeters, of which fully thirteen-fourteenths are filled with starch cells, the embryo occupying no more than one-fourteenth of the space.[1]



Progressive sections of grain of wheat taken at the three axes as indicated, showing shape of grain and position and ratio of ($x$) embryo to ($y$) endosperm. (From microphotographs by Rowlee.)

**61. The Embryo.**—The embryo can be divided into (1) scutellum, or absorbent organ, which on germination causes the dissolution of the endosperm and then transfers it to (2) the vegetative portion. This vegetative portion contains in miniature the first leaves and roots of the new plant. The embryo contains a relatively high per cent of ash, protein and fat, and considerable quantities of soluble carbohydrates (sugar), but probably little if any starch. About one-sixth is fat or oil and about one-third is protein, the two thus constituting one-half of the embryo. The proteids of the embryo differ also from those of the endosperm in the ease with which they undergo changes. Osborne has found the embryo to contain about 3.5 per cent of nucleic acid.[2]

[1] Neb. Bul. 32, p. 103.

[2] Conn. Rcpt. 1901, pp. 365-430.

62. **The Endosperm.**—Under the microscope the endosperm is seen to consist of large elongated thin-walled cells, with their longer axis usually at right angles to the surface of the grain. These cells are filled with starch granules varying in size and form, but when full grown they are rounded or oval in shape and reach a diameter of thirty-seven micromillimeters, or 675 to the inch.[1] The composition of the flour shows the presence of ash and proteids, although under the microscope usually starch only can be seen in the mature grain. M. E. Fleurent has separated the endosperm from the rest of the grain and has subdivided it into three portions from the center outward.[2] There was a material variation in the per cent of gluten in the endosperm of different varieties and a marked variation in successive portions from center outward, both in the per cent of gluten and the proportion of glutenin to gliadin. (70) Proceeding from center outward, the per cent of gluten varied in a French variety from 7.37 to 9.51, in an Indian variety from 8.03 to 10.24, and in a Russian variety from 10.88 to 13.22. The per cent of flour was largest (73.02 per cent) in the Indian variety and least (67.25 per cent) in the Russian variety.

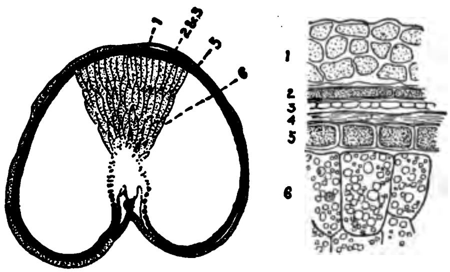
63. **The Aleurone Layer.**—The endosperm, along with the embryo, is enclosed in a single row of comparatively large cells rather regular and rectangular in transverse or cross section. When viewed perpendicular to the surface these cells are irregular in form. The cells are filled with a substance similar in composition and physical properties to that found in the embryo, and are referred to as aleurone or gluten cells. The gluten of wheat flour does not come from the aleurone layer but from the endosperm.

64. **The Bran.**—The aleurone layer is enclosed in the nucellus, which in the mature wheat grain is a single layer of collapsed cells or may be wanting. This is enclosed in the

[1] Neb. Bul. 32, p. 109.

[2] Compt. Rend. Acad. Sci., Paris, 126 (1898), No. 22, pp. 1592-1595.

unripe grain within two layers of cells, the inner and outer integuments of the ovulary. In the mature grain the inner integument may have been absorbed, leaving only the outer, known as the testa. The testa is in turn enclosed by the pericarp, corresponding to the pod in the pea. The pericarp is composed of three rows of cells and constitutes a rather larger portion of the grain than do the testa and nucellus together. These envelopes are sometimes spoken of collectively as the bran. Bessey[1] and Snyder[2] give different portions of the wheat grain as follows:



Cross section of grain of wheat on the left. (From microphotograph by Tolman.) Transverse section, on the right, of an unripe grain enlarged about 100 times from drawing by Bessey. 1, ovary wall or pericarp; 2, outer integument; 3, inner integument; 4, remains of nucellus; 5, aleurone cells; 6, starch cells.

| | Per cent |
|---|---|
| Embryo . . . . . . . . . | 6- 7 |
| Aleurone layer . . . . . . . | 3- 4 |
| Endosperm . . . . . . . . | 82-86 |
| Seed covering or bran . . . . . . | 5 |

Girard gives the per cent of embryo in four varieties of wheat as 1.50, 1.41, 1.35 and 1.16 respectively.[3]

Since the mill products of wheat average considerably less than nine per cent crude fiber, and since seventy per cent of a wheat grain is converted into flour, it follows that the seed coats of the wheat grain must either be considerably less than

1 Neb. Bul. 32, p. 111.

2 Harry Snyder: The Chemistry of Plant and Animal Life, p. 278.

3 Compt. Rend. Acad. Sci., Paris, 124 (1897), p. 878.

five per cent or the seed coats must be largely composed of something else than crude fiber.

65. **Physical Properties.**—Richardson found as the result of 377 determinations that there were about 12,000 grains in a pound of wheat: in some samples there were less than 8,000, while in others 24,000 grains to the pound. Obviously, so far as individual grains are concerned, one bushel of seed in the one case would be equivalent to three bushels in the other. Pammel and Stewart report variations in the specific gravity of American grown varieties from 1.146 to 1.518.

The hardness of the grain varies greatly. Generally the harder grains contain the higher per cent of total nitrogen and of gluten. The relation between hardness and specific gravity has not as yet been clearly demonstrated, although Lyon has shown that high specific gravity is associated with low nitrogen content.[1]

Kornicke and Werner[2] state that the specific gravities of the various chemical constituents of the wheat grain are as follows: Starch, 1.53; sugar, 1.60; cellulose, 1.53; fats, 0.91-0.96; gluten, 1.30; ash, 2.50; water, 1.00; air, .001293.

The standard (and generally legal) weight per bushel (2150.42 cu. in.) of wheat is sixty pounds. The weight of a measured bushel not infrequently varies from fifty-five to sixty-five pounds per bushel, and greater extremes have been noted.

The color of the grain varies from a very light yellow through varying grades of amber to dark red. Hardness of grain and high nitrogen content are usually associated with the deeper red color.

The grain may vary in length, in transverse or cross section outline, or in depth of crease or furrow. All of these characters may be used in describing varieties of wheat. (201)

1 A Method for Improving the Quality of Wheat for Breadmaking. Thesis for degree Ph.D., Cornell, 1904.

2 Handbuch des Getreidebaues Bd. 2s. 120. Berlin, 1884.

## II. COMPOSITION.

**66. Composition.**—The following table gives the minimum, maximum and average analyses of 310 American grown samples of grain and seven samples of wheat straw:[1]

| | Grain | | | Straw | | |
|---|---|---|---|---|---|---|
| | Min. | Max. | Aver. | Min. | Max. | Aver. |
| Water | 7.1 | 14.0 | 10.5 | 6.5 | 17.9 | 9.6 |
| Ash | 0.8 | 3.6 | 1.8 | 3.0 | 7.0 | 4.2 |
| Protein (N x 6.25) | 8.1 | 17.2 | 11.9 | 2.9 | 5.0 | 3.4 |
| Crude fiber | 0.4 | 3.1 | 1.8 | 34.3 | 42.7 | 38.1 |
| Nitrogen-free extract | 64.8 | 78.6 | 71.9 | 31.0 | 50.6 | 43.4 |
| Fat | 1.3 | 3.9 | 2.1 | 0.8 | 1.8 | 1.3 |

**67. Water.**—The analyses show that wheat contains ten to eleven per cent of water. This represents the moisture in the samples as analyzed, often after they have stood in the dry room of the laboratories. What percentage of water wheat contains as it goes on the market cannot be stated, but it has been shown to vary largely from day to day with varying conditions of the atmosphere. In California, where the atmosphere inland is very dry at harvest, this subject is a matter of considerable commercial importance. It is claimed that the moisture that this California wheat will absorb during a voyage from San Francisco to Liverpool will sometimes increase its weight enough to pay the entire cost of freight. Wheat bought inland and kept in warehouses all the season would increase in a similar manner upon exposure.

Experiments by Hilgard and O'Neil, of the University of California, indicated that wheat of the inland of California might increase twenty-five per cent in weight by the absorption of water when transported to a temperate climate, while a gain of five to fifteen per cent might be looked for with absolute certainty. A difference of nine per cent was observed in twenty-four hours. Brewer found a difference of from five to

[1] U. S. Dept. of Agr., Office of Exp. Stations E. S. B. 11.

eight per cent of water in wheat in a room in which the moist air of New Haven circulated in September and in February when the room was heated by a furnace. Richardson found that two days were sufficient to equalize the moisture in samples of flour which originally varied from less than eight to over thirteen per cent. Afterward the water in the samples fluctuated with the humidity of the air.

68. **Ash.**—Lawes and Gilbert give the average composition of the ash of the grain and straw of wheat on an unmanured plat during twenty years as follows:[1]

| | Grain | Straw |
|---|---|---|
| Ferric oxide | 0.645 | 0.69 |
| Lime | 3.175 | 5.075 |
| Magnesia | 10.48 | 1.525 |
| Potash | 33.345 | 15.355 |
| Soda | 0.18 | 0.265 |
| Phosphoric anhydride ($P_2O_5$) | 50.065 | 3.10 |
| Sulphuric anhydride ($SO_3$) | 1.42 | 3.84 |
| Chlorine | 0.05 | 2.13 |
| Silica | 0.655 | 68.505 |
| Total | 100.015 | 100.485 |
| Deduct O=Cl | .015 | .485 |
| Total | 100.00 | 100.00 |

Fifty per cent more phosphoric acid than potash is laid up in the grain, while in the straw five times as much potash as phosphoric acid is accumulated. A relatively large amount of magnesia is stored in the grain, while relatively more lime is to be found in the straw. More than two-thirds of the ash of straw is silica. Formerly it was held that the silica helped to stiffen the straw. This view is no longer held, since the accumulation of silica is greater in the upper portion of the stem.

It has been shown that the ash constituents of normally ripened seeds of wheat are remarkably uniform, but vary some-

[1] Jour. Am. Chem. Soc. Vol. XLV (1888), p. 100.

what with the season, as does the nitrogen, on account of irregularities in the ripening of the seed, and only slightly on account of different modes of manuring except in cases of abnormal soil exhaustion. From three plats manured as indicated in the table below, Lawes and Gilbert found the average annual yield of total mineral constituents during sixteen years to be as follows:[1]

| | In Grain Lb. | In Straw Lb. | Total Lb. |
|---|---|---|---|
| By farm yard manure . | 36.3 | 201.1 | 237.4 |
| Without manure . . | 16.6 | 89.5 | 106.1 |
| With ammonium salts alone | 23.0 | 119.2 | 142.2 |

Where ammonium salts alone were used the grain showed exhaustion both of potash and phosphoric acid—especially the latter, while in the straw there was a marked deficiency of the former.

69. **Protein.**—In 310 analyses of American grown wheats compiled to September 1st, 1890, the protein (N x 6.25) varied from 8.1 to 17.2 per cent, with an average of 11.9 per cent in samples containing an average of 10.5 per cent water, or in other words, the protein was 13.3 per cent of the dry matter of the grain. Koenig reports the range in protein of the wheat grain from various parts of the world to be from five to twenty-four per cent, but that seventy-five per cent of all analyses fall within eight to fourteen per cent.[2]

The nitrogenous compounds of wheat consist principally, if not wholly, of proteids, of which five have been recognized and studied by Osborne and Voorhees as follows:[3] (1) a globulin, 0.6-0.7 per cent of the grain; (2) an albumin, 0.3-0.4 per cent; (3) a proteose, 0.2-0.4; (4) gliadin, 4.25 per cent; and (5) glutenin, 4-4.5 per cent. (71, 72)

1 Jour. Am. Chem. Soc. Vol. XLV (1888), p. 20.

2 U. S. Dept. of Agr., Div. of Chem. Bul. 4, p. 69.

3 The Proteids of the Wheat Kernel. By Thomas B. Osborne and Clark C Voorhees. Am. Chem. Jour. XV (1893), pp. 392-471.

**70. Gluten.**—Wheat flour has the property in common only with rye flour of forming a dough when mixed with water which on leavening and baking produces a porous bread. This is due to the gluten which imprisons the carbonic acid gas caused by the fermentive action of the yeast. The gas expanding during leavening and during baking causes the bread to become porous.

Gluten is a mixture of gliadin and glutenin and may be obtained in a crude state from wheat meal or flour, by washing the dough made by kneading the meal with water, which removes starch and other non-gluten compounds. Moist gluten contains about sixty-six per cent of water and certain other impurities which are in fairly constant proportions in different samples. A good gluten has a light yellow color, is tenacious and elastic, while poor gluten is dark in color, is sticky but not elastic.

"The gliadin with water forms a sticky medium, which by the presence of salts is prevented from becoming wholly soluble. This medium binds together the particles of flour, rendering the dough and gluten tough and coherent. The glutenin imparts solidity to the gluten, evidently forming a nucleus to which the gliadin adheres and from which it is consequently not washed away by water. Gliadin and starch mixed in the proportion of 1 : 10 form a dough, but yield no gluten, the gliadin being washed away with the starch. The flour freed from gliadin gives no gluten, there being no binding material to hold the particles together so that they may be brought into a coherent mass.

"Soluble salts are also necessary in forming gluten, as in distilled water gliadin is readily soluble. In water containing salts it forms a very viscid, semi-fluid mass, which has great power to bind together the particles of flour. The mineral constituents of the seeds are sufficient to accomplish this purpose, for gluten can be obtained by washing a dough with distilled water."

The amount and quality of gluten—especially the latter—is what gives the flour its baking qualities. The quality of the gluten is due in part at least to the proportion of gliadin and glutenin. M. E. Fleurent states that the most favorable ratio of glutenin to gliadin is twenty-five of the former to seventy-five of the latter. He gives analyses of two varieties which are in the ratio of 23 : 77 and 30 : 70 respectively, and suggests that

the breadmaking value of the flour may in such cases be increased by mixing in proper proportions the wheat or the flour made therefrom.[1] Snyder states that the most valuable wheats for breadmaking are those in which eighty to eighty-five per cent of the protein is gluten and the gluten is composed of thirty-five to forty per cent glutenin and sixty to sixty-five per cent gliadin. He reports a variety of wheat from India with a ratio of 27 : 73 and one from the Argentine Republic with a ratio of 58 : 42.[2] The value of a flour depends, therefore, more relatively upon the quality of the gluten than upon the per cent of the nitrogenous compounds contained.

71. GLIADIN.—With water containing salts or mineral matter gliadin is a plastic substance which may be drawn out into sheets or strings. By proper chemical manipulation it may be reduced to a snow-white powder. When distilled water is added to this powder it becomes sticky, but if a ten per cent solution of salt (sodium chloride) is added, it is non-adhesive, although plastic. Gliadin is soluble in distilled water, very soluble in seventy to eighty per cent alcohol, but is insoluble in water containing salts or in absolute alcohol. It is soluble in dilute acid and alkalis and may, therefore, be soluble in wheats that have undergone fermentation.

72. GLUTENIN.—Is the proteid which is left after dissolving the gliadin from the gluten with dilute alcohol. It is distinguished from gliadin by its lesser solubility, its darker color, and by being non-adhesive and non-plastic. It is insoluble in water, saline solutions and dilute alcohol, but is soluble in dilute acids and alkalis, from which it may be precipitated by neutralization.[3]

73. **Relation of Weight Per Bushel to Nitrogen Content.**—The usual and commercial standard of quality in wheat is the weight per bushel, high weight being associated with qualities desired by the miller. The following table gives the results of eight favorable seasons for wheat and eight unfavorable seasons with three conditions of fertility at Rothamsted:[4]

[1] Compt. Rend. Acad. Sci., Paris, 126 (1898), No. 22, pp. 1592-1595.

[2] The Chemistry of the Wheat Plant, pp. 276-277.

[3] The Proteids of the Wheat Kernel. By Thomas B. Osborne and Clark C. Voorhees. Am. Chem. Jour. XV (1893), pp. 470-471.

[4] Lawes, Sir J. B., and J. H. Gilbert. On the composition of the ash of wheat, grain and straw, grown at Rothamsted in different seasons and by different manures. London (1884), pp. 105.

**Influence of Season and Fertilizers Upon Wheat.**

| | Wt. per bu. lb. | Grain to straw Per cent. | Grain per acre lb. | Straw per acre lb. | Nitrogen in dry matter Per cent. | Ash (pure) in dry mat'r % |
|---|---|---|---|---|---|---|
| Average of eight favorable harvests: | | | | | | |
| Plat 2—Farm yard manure . . | 62.6 | 62.5 | 2342 | 6089 | 1.73 | 1.98 |
| Plat 3—Unmanured | 60.5 | 67.4 | 1156 | 2872 | 1.84 | 1.96 |
| Plat 10A—Ammonium salts alone . | 60.4 | 66.2 | 1967 | 4774 | 2.09 | 1.74 |
| Average of eight unfavorable harvests: | | | | | | |
| Plat 2—Farm yard manure . . | 57.4 | 54.5 | 1967 | 5574 | 1.96 | 2.06 |
| Plat 3—Unmanured | 54.3 | 51.1 | 823 | 2433 | 1.98 | 2.08 |
| Plat 10A—Ammonium salts alone . | 53.7 | 46.7 | 1147 | 3601 | 2.25 | 1.91 |

It will be seen that in seasons unfavorable for the yield the weight per bushel was light but the nitrogen content as well as the ash content was high, and on the other hand that in seasons of favorable growth the weight per bushel was high and the nitrogen and ash content were low. In these cases, covering a series of years and several conditions of fertilization, high weight per bushel was associated with large percentage of starch. Lawes and Gilbert conclude that "High percentage of nitrogen is by no means a characteristic of the wheats held in highest estimation either by the miller or the baker; and that so far as both the baker and consumer are concerned the condition of nitrogenous matters is of more importance than their total amounts. Comparing one description of wheat with another, the one with a relatively high percentage of nitrogen may be better, provided the grain be at the same time fully ripened and not too horny. But when the percentage exceeds a certain limit, the grain is generally either too hard, or there is deficient storing up of starch and an unfavorable condition of the nitrogenous substances."

**74. Influence of Environment on Composition of Grain.**—Environment is a combination of influences of which the following three are the most important:

1. Climate.
2. Soil, including fertilizers of all kinds.
3. Culture, including preparation of seed bed, time and method of seeding and quantity of seed, etc.

It has been shown that the composition of the wheat grain varies in different localities when grown from seed of a common origin. For example, Richardson found that the per cent of protein in a number of varieties of wheat was considerably higher when grown in Colorado than when grown in Oregon. He also found that the grains of wheat were much larger when grown in Oregon than when grown in Colorado. Deherain makes a similar observation with regard to the influence of different seasons. High temperature during July (in France) increased the per cent of protein but diminished the yield so that the amount of the protein was no greater than under normal conditions. The high per cent of protein in the hard spring wheats of the northwest is likewise attributed to the arrested development of the endosperm or starchy portion of the grain.

Richardson attributes the variation in the per cent of protein to the differences in soil and attributes low per cent of protein found in some American wheat to a deficient supply of nitrogen. Lawes and Gilbert state that the low percentage of nitrogen is more probably due to the enhanced formation of starch under the influence of high ripening temperatures, and that, comparing the grain grown from the same description of seed but on different soils, or in different seasons, high percentage of total nitrogenous matter is almost invariably coincident with inferior ripening. Wiley attributes the variation in per cent of protein to climatic conditions, but attributes variation in the ash occurring in the same varieties of wheat to the soil and fertilizers.[1]

[1] Influence of Environment on the Composition of Plants. By H. W. Wiley. Yearbook, Dept. of Agr., 1901, p. 306.

Carleton believes that localities with black soils (high in organic matter) and extreme climatic variations are most favorable for the production of high protein content. William E. Edgar says:

"Gradually as the northwestern States have become cultivated the original hard wheat has grown scarcer. Wheat raised on virgin lands has a peculiar strength lacking in that produced in older fields. It is capable of improving the character of other wheat blended with it when the mixture is made into flour." [1]

Lawes and Gilbert, in an elaborate series of analyses of wheats grown on unmanured and variously manured plats during twenty seasons, have shown the variation in composition of wheat to be much more influenced by season than by manuring. There was very little variation in the mineral composition of the wheat grain accorded to manuring except in cases of abnormal exhaustion. Commenting upon the significance of the facts presented, the authors say:

"The character of development of a crop left to ripen, depends very much more upon season than upon manuring. Indeed, if one crop (of wheat for example) grows side by side with another of exactly the same description, but yielding under the influence of manure twice the amount of produce, and both under such conditions of season that each fully and normally ripens, the composition of the final product, the seed, will be very nearly identical in the two cases. In other words, there is scarcely any difference in the composition of the truly and normally ripened seed. But, as variations of season affect the character of development, and the conditions of maturation, there may obviously be, with these, very wide differences in the composition of the product. The wide range in the composition of the ash of the grain, which the table shows according to season, represents in fact a corresponding deviation from the normal development." [2]

The climatic condition which seems most uniformly to affect the composition of the grain is the length of season of growth. The shorter the season of growth, the higher the percentage of protein and the lower the percentage of starch. Doubtless the shorter the season of growth, the smaller the grain.

It does not follow that strains may not be selected which will contain high per cents of protein and at the same time produce more protein per acre, although the facts stated above suggest that difficulty may be found in doing so.

[1] The Story of a Grain of Wheat, p. 126. New York, D. Appleton & Co., 1903.

[2] Lawes and Gilbert on the composition of the ash of wheat-grain and wheat-straw, p. 8.

75. **Germination.**—Wheat absorbs upon germination from five to six times its weight of water. Various experimenters have reported that dilute solutions of fertilizers and other salts accelerate germination. The salts dissolved in soil water probably exert a favorable influence. Whether this is a physical or physiological influence has not been proven, but it has been shown that absorption of water goes on as rapidly in dead seeds as in live ones.[1]

More concentrated solutions used to prevent smut have in some instances been reported injurious. Much less injury is done by soaking the seeds in the solution before sprouting than by bringing the solution in contact with the young plantlet. It has been shown that nitrate of soda and muriate of potash when used in too large quantities or not properly distributed in the soil may destroy germination, while fertilizers composed of lime and phosphoric acid are much less injurious.[2] In no case should the seeds be brought in direct contact with nitrate of soda and muriate of potash.

Sachs gives the minimum and maximum temperatures at which wheat will germinate as 41° F. and 108° F., and the most favorable temperature as 84° F. Haberlandt reports that wheat germinated at 41° F. at the end of six days, that the maximum temperature of germination was between 88° and 100° F., and that the most favorable temperature was somewhere between 61° to 88° F.[3]

Saunders determined the viability of three varieties of wheat during six years with the following average results: 80; 82; 77; 37; 15; 6 per cent.[4] The germination ability showed a marked decrease at the end of four years, and at the end of six years was entirely lost in two of the three varieties.

1 Wyo. Bul. 39, p. 44.

2 U. S. Dept. of Agr., Div. of Bot. Bul. 24.

3 Landw. Vers.—Stat. XVII, 104.

4 Can. Expt. Farms Rpt. 1903, p. 44.

# IV.

## WHEAT.

### I. BOTANICAL RELATIONS.

76. **The Wheat Genus** (*Triticum* L.).—The plants of this genus are all annuals. The commonly cultivated species have apparently been so changed from the wild type as to be dependent upon man's agency for their existence. Sir John Lawes was wont to say that if man should disappear from the earth wheat would follow him in three years. This is true, also, of the common field bean, maize, tobacco, and a few other less commonly grown species.

Hackel divides the genus into two sections, viz., *Ægilops* L. and *Sitopyros*.[1] In the former the glumes are flat or rounded on the back, while in the latter they are distinctly keeled. To the latter section belong the cultivated species.

77. **The Species of Wheat.**—There are eight cultivated types of wheat which are usually considered of greater value than the variety type. Hackel recognizes but three true species and the other types are treated as subspecies.[2]

The structural relationship is much closer between *Tr. sativum* and *Tr. polonicum* than between *Tr. monococcum* and either of the former. The palea of *Tr. monococcum* falls into two parts at maturity, while in the other two species the palea remains entire. *Tr. sativum spelta* and *Tr. sat. dicoccum* are to be distinguished from the other four subspecies of *sativum* by the grains remaining enclosed in the glumes upon threshing and by the rachis breaking up at maturity. The common and

1 In the following division into species and subspecies Hackel has been followed. See The True Grasses. By Edward Hackel. Translated from Die Naturlichen Pflanzenfamilien by F. Lamson-Scribner and Effie A. Southworth, pp. 179-187.

2 Ibid.

club wheats are closely related to each other, as are likewise the poulard and durum wheats. Einkorn never, and the polish wheat rarely, gives rise to a fertile cross with common wheat. The subspecies of *Tr. sativum* readily cross with each other.

The relationship of the eight types is shown in the following outline:

- *Triticum*
  - *monococcum* (1) einkorn
  - *sativum*—
    - *spelta* (2) spelt
    - *dicoccum* (3) emmer
    - *tenax*—
      - *vulgare* (4) common wheat
      - *compactum* (5) club or square head wheat
      - *turgidum* (6) poulard wheat
      - *durum* (7) durum wheat
  - *polonicum* (8) polish wheat

Einkorn.
(One-half natural size.)

78. **Einkorn** (*Tr. monococcum* L.).—This species may be distinguished from the other species by the palea falling into two pieces at maturity. The joints of the rachis readily separate as in the case of the wild species of this genus. Usually only the lower flower of the spikelet matures. Each spikelet is awned and the spike is compact. The wild type is scarcely distinguished from the cultivated type. It is cultivated somewhat in Europe in poor and rough places unsuited for other varieties of wheat. Its cultivation is of great antiquity, as is proven by finding the grain in the Lake dwellings belonging to the

Stone Age. It is used for mush and cracked wheat, and as fodder for cattle, rather than for bread.

79. **Spelt** (*Tr. sativum spelta* Hackel).—Was largely and widely cultivated in ancient times. Hackel states that it was the chief grain in Egypt and Greece and was cultivated everywhere throughout the Roman Empire and distributed through its colonies. It is now sparingly cultivated in Europe except in northern Spain, where it is still an important crop. At present it is used almost exclusively as a stock food. It is not cultivated in this country except in an experimental way. There are both winter and spring varieties, but the winter beardless spelt, a white-spiked, awnless variety, is said to be the most profitable. Under ordinary conditions the yield is not equal to common wheat. Hackel states that it is more certain, liable to fewer diseases and not at all subject to the attacks of birds. Carleton says that it is especially liable to rust. He gives its desirable qualities as power to hold the grain in the spike, constancy in fertility, and hardiness of certain winter varieties.[1] The brittleness of the spike is an undesirable quality.

Spelt.
(One-half natural size.)

The Garton Brothers (England) have obtained good results by crossing spelt on common wheat to prevent shattering at harvest.

80. **Emmer** (*Tr. sat. dicoccum* Hackel).—Hackel states that this subspecies has been "cultivated from the most ancient times but always more sparingly than spelt and at present (1885) only in S. Germany, Switzerland, Spain, Servia and Italy." Carleton (1900) says: "Very little, if any, true spelt is grown in

1 The Basis for the Improvement of American Wheats. By M. A. Carleton. U. S. Dept. of Agr., Div. Veg. Phys. and Path. Bul. 24, p. 34.

Russia, though a rather large quantity of emmer is produced each year." This species is often incorrectly called spelt in the United States and the two species are thus sometimes confused.

"The plants of this species are pithy or hollow, with an inner wall of pith; leaves sometimes rather broad, and usually velvety hairy; heads almost always bearded, very compact, and much flattened on the two-rowed sides. The appearance in the field is therefore quite different from that of spelt. The spikelets, however, look considerably like those of spelt, but differ principally in the presence always of a short pointed pedicel. This pedicel, which is really a portion of the rachis of the head, if attached at all to the spelt spikelets, is always very blunt and much thicker. Besides, the emmer spikelets are flattened on the inner side, and not arched as in spelt, so that they do not stand out from the rachis as the spelt spikelets do, but lie close to it and to each other, forming a solidly compact head. The spikelets are usually two-grained, one grain being located a little higher than the other. The outer chaff is boat-shaped, keeled, and toothed at the apex. The grain is somewhat similar to that of spelt, but is usually harder, more compressed at the sides, and redder in color.

Common wheat: Turkish red variety on the left; Red Fultz variety on the right.

"For the production of new varieties by hybridization emmer has qualities similar to those of spelt, but still more valuable. At the same time emmer, besides possessing harder grain, is more resistant to drought, and usually rather resistant to orange leaf rust. It is well adapted for cultivation in the northern States of the Plains and has already proved very valuable as a hardy forage plant in that region,

besides giving a good yield of grain per acre. Almost all varieties are spring grown. Of other countries emmer is chiefly cultivated in Russia, Germany, Spain, Italy and Servia, and to some extent in France. The emmer of this country is descended from seed originally obtained chiefly from Russia, where a considerable portion of the food of the Volga region is a sort of gruel ("kasha") made from hulled and cracked emmer.

"The desirable qualities furnished by this group of wheats are:

(1) Power of holding the grain in the head.

(2) Drought resistance.

(3) Resistance to orange leaf rust.

"The undesirable qualities are:

(1) Brittleness of the head.

(2) Adaptability only for spring sowing."[1]

81. **Common Wheat** (*Tr. sat. vulgare* Hackel).—As the name implies, this is the subspecies commonly grown throughout the wheat growing districts of the world. Its high yielding power and its excellence for breadmaking are the special qualities which have made it the leading cultivated sort.

82. **Club or Square Head Wheat** (*Tr. sat. compactum* Hackel).—This subspecies differs from common wheat principally in the shortness and compactness of the head and the shortness (usually about two feet) and stiffness of the straw. It is less liable to shatter before or during harvest and less liable to lodge than common wheat, and is thus especially adapted to the Pacific Coast States and those Rocky Mountain States where the wheat stands on the field for some time after it is ripe and is cut with combined header and thresher. Aside from the regions named it is cultivated chiefly in Chile, Turkestan and Abyssinia. There are both spring and winter varieties. The latter are adapted only to comparatively mild climates. The quality of the grain does not differ materially from that of the softer varieties of common wheat.

Club wheat.
(One-half natural size.)

1 The Basis for the Improvement of American Wheats. By M. A. Carleton U. S. Dept. of Agr., Div. of Veg. Phys. and Path. Bul. 24 (1900), pp. 34-35.

83. **Poulard Wheat** (*Tr. sat. turgidum* Hackel).—This subspecies is not grown in this country except in an experimental way. It is grown chiefly in the hot dry regions bordering the Mediterranean and Black Seas. It is frequently called English wheat, although it is not grown in England. It is so closely allied to durum wheat as to be hardly distinguished from it, especially in some varieties. It differs chiefly in having a broader spike, shorter beards, shorter and less dense grains and stiffer straw. Some varieties of this subspecies have branching spikes and are known as Egyptian wheat or the wheat of miracle (*Tr. compositum* L.). *Tr. compositum* is simply a sport and is of no value.

84. **Durum Wheat** (*Tr. sat. durum* Hackel).—The varieties of this subspecies are commonly referred to in this country as macaroni wheat, because they have been principally used in Europe for the manufacture of semolina, the manufactured material from which macaroni and other forms of edible pastes are produced. Durum wheat is superior to common wheat for this purpose on account of its higher gluten content and greater density. The South Dakota Station has shown that bread of fine flavor with a dark color somewhat resembling rye bread can be made from it. Millers generally avoid buying it for ordinary bread flour. It is hoped that the manufacture of macaroni may be stimulated in this country, which it is believed would increase its use, because freshness is an important

Curing semolina in the open air.
Factory of F. Scaramelli Fils, Marseilles, France. This firm exports large quantities of macaroni to the United States.

attribute of high class macaroni. Heretofore most of the macaroni has been imported, the domestic article not having been altogether satisfactory. This has been due in part, it is believed, to lack of good macaroni wheat and in part to lack of technical skill in the manufacture of the semolina.[1]

"The macaroni wheats are tall, with broad, smooth leaves. The heads are heavily bearded, being much more so than any of the ordinary wheats, and the plant when bearded has much the appearance of barley. The heads are large and vary in color from light yellow to almost black, depending upon the variety. The kernels are large, very hard, having less starch than common wheat. They vary from light yellow to reddish yellow in color. The habits of growth of durum wheats adapt them to regions of light rainfall. They have great ability to withstand drouth and heat but require a rich soil, although they are notably tolerant of alkali. In some mild climates durum wheats are sown in the fall, but generally they are grown as spring wheat."[2]


Durum wheat.
(One-half natural size.)

The natural habitat of durum wheat is about the same as that of poulard wheat. In Spain it is more largely grown than any other type. It is also grown considerably in South and Central America, whence it has found its way into Texas under the name of Nicaragua wheat. Another variety has been grown successfully in parts of the Northwest and Canada under the name of Wild Goose. The varieties of durum wheat tested at the stations have

1 Manufacture of Semolina and Macaroni. U. S. Dept. of Agr., Bu. of Pl. Ind. Bul. 20.

2 Neb. Bul. 78, p. 4.

come principally from Russia and Algeria. The former seem to be superior to the latter, which suggests that the best results will be obtained in more northerly portions of the semiarid section of this country.

The durum wheat does not tiller as freely as common wheat. The South Dakota Station recommends six pecks of seed where five pecks of common wheat are used. Otherwise the culture of durum wheat is similar to that of common wheat.

85. **Polish Wheat** (*Tr. polonicum* L).—This species may be distinguished from the common varieties of wheat by the palea of the lowest flower, which is half as long as the flowering glume, while in the latter the palea is as long as its glume. In the polish wheat the outer glumes are as long or longer than any of the flowering glumes, while in the common varieties the outer glumes are shorter. The grains of polish wheat are large and somewhat resemble rye, which accounts for the wheat being sometimes called Giant or Jerusalem rye. The glumes are blue-green, the spikelets rather long, close to rachis, giving spike a striking appearance. This wheat is cultivated somewhat in southern Europe, but is ordinarily not considered productive. It is believed by Carleton to be adapted to the arid districts of this country. It is adapted for the production of macaroni but not for breadmaking.

Polish wheat.
(One-half natural size.)

86. **Spring and Winter Wheat.**—There are spring and winter varieties of all the species and subspecies of wheat except emmer, which is a spring variety only. Linnaeus divided common wheat into two separate species, calling winter wheat *Tr. hybernum* and spring wheat *Tr. oestivum*. It has been shown, however, by direct experiment that winter wheat may be changed to spring wheat

and spring wheat to winter wheat. M. Mouries sowed winter wheat in the spring and out of one hundred plants four alone ripened seeds. These were sown and resown and in three years plants were reared which ripened all their seeds. Conversely, nearly all the plants raised from spring wheat sown in the autumn perished from the cold, but a few were saved and produced seed. In three years this spring variety was converted into a winter variety. This is a striking example of the climatic adaptability of wheat. It shows that a variety which possesses valuable characteristics, although lacking hardiness, may be worth attempting to grow, provided intelligent selection is exercised until it becomes adapted to the climate.

## II. CLASSIFICATION OF VARIETIES.

87. **The Importance of Variety.**—The variety has much to do with the successful culture of wheat in each individual instance. Except in the possible extra outlay for seed, it costs no more to raise twenty bushels from a good variety than fifteen bushels from a poor variety. If, on the other hand, the yield is increased by the use of fertilizers or by better preparation of the seed bed, the increase is made at some expense, more or less considerable. (29)

88. **The Best Variety.**—There is no best variety for the whole country. Not only do good varieties in one locality prove poor varieties in another, but sometimes a variety which one year gives the largest yield of fifty varieties, sown the next year in the same locality is one of the poorest yielders. Nevertheless, careful and systematic tests covering a decade or more by several experiment stations show that certain varieties are on an average of years decidedly superior to other varieties in the given locality and for the particular soil and methods of culture. Hays estimates that the Minnesota Station has made possible the increase in the yield of wheat in Minnesota one to two bushels per acre, or five to ten per cent, through the introduc-

tion of Minnesota No. 169. A list of some of the best varieties as shown by the results of station tests is given elsewhere. (96, 97, 98, 99)

89. **Variety Names.**—One reason which makes the comparative merits of varieties so confusing is that many names are given to the same variety. It is not unusual for old and well-known varieties to be put on the market with high sounding names and extravagant praises. Probably the re-naming of old varieties is to some extent intentional deception, but doubtless much of it is done through ignorance. A wheat raiser procures fresh seed from some source without knowing the name of it, and finds after growing it a year or two that it is better than that grown by his immediate neighbors. This leads to a local name, given either by the grower or the buyers. The better the variety and the more extensively it is grown, the larger the number of names it is likely to receive. Different varieties, also, although less frequently, sometimes have the same name. Often fancied or real improvement has taken place. It would often be difficult to decide when a strain has varied sufficiently to justify its having a new name.

90. **Pedigree Wheat.**—To protect both the purchaser of seed wheat and the producer of superior varieties, it has been proposed to establish a register for recording varieties of wheat and other field crops. This record would be accompanied by a statistical pedigree of the variety and there would be just the same opportunity of judging the source and value of the variety as there now is for judging these qualities in registered breeds of live stock. By statistical pedigree is meant that the yield of the crop in each generation would be on record. If the yield of a lineal ancestor of a particular strain of a given variety were known for a number of generations, together with the name of the grower, the locality, character of soil, and method of culture of each generation, the purchaser would have an intelligent and consistent basis for judging its value. Whether this register

could best be conducted by breeders' associations, by the State or National agency is still an unsettled question. In the meantime there is an opportunity for breeders to form associations and reap a benefit similar to that obtained by live stock breeders' associations.

91. **Number of Varieties.**—In 1895 the United States Department of Agriculture collected about 1,000 rather distinct varieties of wheat, having obtained varieties from every wheat country of the world. After three years' trial less than 200 varieties were selected as being worthy of continued trial. After five years' trial, it was determined that in all the species and subspecies of wheat there were 245 which may be regarded as leading varieties of the world, at least so far as they have any adaptability to American conditions.

92. **Variety Characteristics.**—The following are some of the characteristics which may be taken to constitute variety differences: color, shape and hardness of grain, color and smoothness of glumes, glumes bearded or beardless, time of ripening, length and other characters of straw. If grown under like conditions, probably the size of the grain, when the differences are marked, should be considered. With winter wheat the time of ripening is not a very important characteristic through much of the winter wheat area. The Ohio Station finds usually about twelve days as the extreme difference in sixty-five varieties tested, although a difference of sixteen days has been noted. This station is confirmed in the belief that seasons which produce early maturity give crops of better quality.[1] Hays found among 400 plants of a single spring variety that the time of ripening varied from 97 to 127 days.[2] In those States west of the Missouri River where hot dry winds frequently prevail during the ripening period, especially if delayed, earliness of maturity

[1] Ohio Bul. 129, p. 18.

[2] Minn. Bul. 62 (1899) p. 424.

is essential to successful wheat culture. A number of otherwise desirable varieties cannot be successfully grown on account of their lateness in maturing.

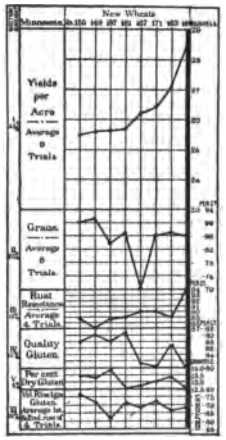
93. **Variety Groups.**—The different varieties can be divided easily into eight groups in accordance with three external characters as follows:

| | | | |
|---|---|---|---|
| Wheat | Bearded | Glumes white | Grain red—1 |
| | | | Grain white—2 |
| | | Glumes bronze | Grain red—3 |
| | | | Grain white—4 |
| | Beardless | Glumes white | Grain red—5 |
| | | | Grain white—6 |
| | | Glumes bronze | Grain red—7 |
| | | | Grain white—8 |

In some varieties with bronze glumes the glumes are velvety instead of smooth, as is usually the case. The color of the grain varies from a light yellow, usually called white, to a deep red. In some cases the intermediate color is referred to as amber. In the markets wheat is referred to as either red or white. With the exceptions just noted, different varieties coming in any one of the eight groups will usually resemble each other closely and need to be subjected to a rigid test to determine their right to be called separate varieties. Beardless varieties with red berries are the most numerous and most generally cultivated. It has not been demonstrated that there is any difference in yield between red and white or bearded and beardless wheats. Two thousand years ago Columella recommended bearded wheats for low moist land and beard-

less wheats for dry upland. The variety which the Ohio Station especially recommends for lowland is bearded, while the two highest yielding varieties upon upland soil in nine years' test are beardless. Some bearded varieties, however, have also yielded nearly as well upon upland soil. Red grains command the highest price because of their superior milling qualities.

94. **Desirable Qualities.**—The three characteristics which determine the eight groups above are external and in themselves are not essential, although they may be correlated with essential qualities. Nilsson holds that the purely botanical characters have correlated with them such valuable economic ones that too much stress cannot be laid upon the value of a pure botanical variety.[1] Some of the qualities which it is desirable to obtain in wheat are:



Graphic score card comparing wheats.

(1) High yield.
(2) Hardness and density of grain.
(3) For some purposes and within certain limits high gluten content of superior quality.
(4) Early maturity (at least for some sections.)
(5) Resistance to drought.
(6) Resistance to rusts.
(7) Resistance to Hessian fly.
(8) Stiffness of straw.

Some of these qualities are interdependent, as for example high yield and resistance to drought, rusts or Hessian fly, and some are probably antagonistic, as high yield and high gluten content.

[1] E. S. R. XIII (1902), p. 817.

95. **Score Card.**—Hays has proposed a score card for comparing the *performance* of spring varieties of wheat, as follows:[1]

Percentage score card for comparing varieties of wheat:

| | | |
|---|---|---|
| (1) | Yield per acre | 45 |
| (2) | Grade of grain (market estimation) | 20 |
| (3) | Rust resistance | 10 |
| (4) | Quality of gluten | 10 |
| (5) | Amount of gluten | 5 |
| (6) | Coefficient of rise of gluten | 10 |
| | | 100 |

A graphic presentation of this score card is proposed, as shown in paragraph 94.

96. **Market Classification.** — The markets of the country recognize four types of wheat, which are grown in somewhat distinct areas of the country, although no sharp line can be drawn between these localities. They are as follows:

1. Soft winter, in eastern United States; climate mild, even and moist; spike either bearded or beardless, but principally the latter; color of grain varies from white to light red; per cent of gluten medium.

2. Hard winter, south of Minnesota and the Dakotas between the Mississippi River and the Rocky Mountains; extremes of temperature and moisture with dry, hot summers; usually bearded; grain red, with per cent of gluten high.

3. Hard spring, in Minnesota, the Dakotas and northern Wisconsin, Iowa and Nebraska;[2] climate too severe for winter varieties, otherwise like hard winter district; bearded or beardless; color of grain red and usually lacking in plumpness; per cent of gluten high.

4. White, in Pacific Coast and Rocky Mountain States; long season of growth; bearded or beardless; grain white, large and plump; per cent of gluten low.

[1] Minn. Bul. 62 (1899), p. 432.

[2] Central and western Canada also furnishes a large quantity of this type.

To what extent the varieties of these regions were made so directly by the environment under which they have been grown, and to what extent they are simply the survival of the fittest is still open to further investigation. To put it in other words, the characters may have been acquired through their present environment, or the present varieties may have been selected as the best of a large number of varieties tested in each region.

97. **Soft Winter Varieties.**—Seven stations, including Guelph, Canada, located east of the Mississippi River, have reported tests of varieties of wheat within the past decade. The following varieties have been reported as having given superior yields at two or more stations:

BEARDED, red or amber grain: Valley, Nigger, Mediterranean, Rudy, Fulcaster, Kansas Mortgage Lifter.

BEARDED, white grain: Early Genesee Giant.

BEARDLESS, red or amber grain: Mealy, Early Ripe, Poole, Currell's Prolific, New Monarch, Improved Poole, Fultz, Harvest King, Early Red Clawson.

BEARDLESS, white grain: Dawson's Golden Chaff.

Fultz is probably the most widely and universally grown variety of wheat in the United States. (103) It is what may be called a semihard, red-grained beardless variety with white smooth glumes. Red Fultz (synonyms, Poole and German Emperor) is also largely grown, but differs from Fultz in having bronze smooth glumes.

98. **Hard Winter Varieties.**—The favorite variety of the hard winter wheat is the Turkey (sometimes called Crimean), a bearded, hard red wheat, coming originally from Crimea and other portions of Laurida in southern Russia.

After testing the comparative hardiness and yield of 275 varieties of wheat, covering a series of years, the Kansas Station recommends three bearded varieties, Andrews No. 4, Turkey and Valley, and three beardless varieties, Tasmanian Red,

Ramsey and Currell.[1] Sibley's New Golden (bearded) gave the largest average yield during six years at the Oklahoma Station.[2]

99. **Hard Spring Varieties.**—The two types of hard spring wheat of which there are many varieties are the Fife and the Blue Stem. Both are beardless with white glumes, which in the Blue Stem are covered with fine velvety hairs but in the Fife are smooth. The Minnesota Station after years of testing 200 varieties of wheat has selected two of the Fife type (Power's Fife and Glyndon) and two of the Blue Stem type (Bolton's Blue Stem and Haynes' Blue Stem) as the best four varieties for combined yield and quality.[3] This station has also originated an improved strain of Glyndon under the name of Minnesota No. 163. Preston, a bearded variety, originated by Dr. William Saunders, Director of the Dominion Experiment Farms, Ottawa, Canada, has given good results at several stations.

Spring varieties of durum and macaroni wheats are now being recommended in the semiarid portion of the spring wheat district. South Dakota reports that macaroni wheat will yield from twenty-five to 100 per cent more than the best Blue Stem and Fife wheats, the difference in favor of the macaroni wheats increasing as the conditions for raising bread (common) wheat become less favorable.[4] At the North Dakota Station the average yield of a number of durum (Russian) varieties during four years (1899-1902) was 30.3, while for the Blue Stem and Fife varieties combined it was 25.9 bushels.[5]

The reports from the Nebraska Station[6] and from the Colorado Station[7] are less favorable, while the Minnesota Station

1 Rpt. Kans. St. Bd. Agr. Quar. ending March, 1902, p. 76.

2 Okla. Bul. 47, p. 44.

3 Minn. Bul. 62 (1899), p. 354.

4 S. Dak. Bul. 77, p. 7.

5 13th Rpt. N. Dak. Sta. (1903), p. 77.

6 Neb. Bul. 78.

7 Col. Press Bul. 17.

states that their experiments have demonstrated the superiority for their conditions of the Blue Stem and Fife varieties of common wheat.[1] As the result of five years' tests, the Montana Station recommends three Fife varieties (Red, Wellman's and McKissock's) and three durum varieties (Kubanka, Russian 2955 and Wild Goose).[2]

**100. White Varieties.**—These varieties are to be found growing in the Pacific Coast States and are largely of the club or square head type. Carleton gives the principal varieties as follows: Australian, California Club, Sonora, Oregon Red Chaff, Foise, Palouse Blue Stem, Palouse Red Chaff, White Winter and Little Club.

### III. IMPROVEMENT OF VARIETIES.

**101. New Varieties.**—The new varieties of wheat in this country have come from three sources: (1) The introduction of foreign varieties; (2) the selection of variations in existing varieties; (3) the crossing of two or more varieties and subsequent selection.

**102. The Introduction of Foreign Varieties.**—Examples of the introduction of valuable varieties from foreign countries are to be found in Mediterranean, a bearded red winter wheat introduced first in 1819 from the islands of the Mediterranean Sea; Fife, a beardless red spring variety, supposed to have been obtained by selection from a winter variety introduced from Russia; Turkey, a bearded red winter variety from southern Russia; and the club varieties of the Pacific Coast, soft bearded varieties both spring and winter, some of them at least coming from Chile.

**103. Improvement by Selection.**—Illustrations of improvement by selection are to be found in Fultz, a red-grained beardless variety, selected from Lancaster, a red bearded variety,

1 Minn. Bul. 62 (1899), p. 393.

2 Eighth An. Rpt. Mont. Sta. (1901), p. 16.

in 1862 by Abraham Fultz, Mifflin county, Penn.; Clawson, a white-grained beardless variety, selected from Fultz in 1865 by Garret Clawson; Gold Coin, a white-grained beardless variety, selected from Diehl Mediterranean, a hybrid with beards and red grains, by Ira W. Green, Avon, N. Y. Probably most of the varieties grown at the present time are the result of simple selection more or less systematic.

104. **Varieties Through Crossing.**—Probably the best known variety in this country produced by simple crossing is Fulcaster, a red-grained, semihard, bearded variety produced in 1886 by S. M. Schindel, Hagerstown, Md., by crossing Fultz and Lancaster. (103) An example of continued crossing with different varieties for several generations is to be found in Early Genesee Giant, a bearded, red-grained variety produced by A. N. Jones, Newark, N. Y. Jones' Winter Fife, Early Red Clawson and many others have been produced in this way.

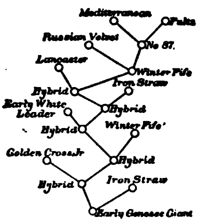


Diagram showing pedigree of Early Genesee Giant. (After Carleton.)

In the varieties just mentioned only varieties of the same subspecies have been used in crossing. John Garton of England, William Farrar of New South Wales and W. Rimpau of Germany have produced wheat hybrids by crossing two or more subspecies, as common wheat, durum wheat and spelt. Where crosses cannot be made directly between two subspecies, it may be accomplished indirectly by first producing a hybrid between one type and an intermediate type. Speaking of plants in general, John Garton says that every two species of plants have a go-between, and given a thousand years he could cross any two plants in the world.

105. **The Possibility of Cross-Fertilization.**—Hackel states that only about one-third the pollen of an anther is deposited on

its own flower, while the rest is deposited into the open air. As the glumes are open upward there would seem to be nothing to prevent the flower below on the same spike from receiving this pollen. Cross-fertilization between flowers of the same spike would seem probable, while cross-fertilization between flowers of different spikes in close proximity would seem possible. In practice, however, it is found that different varieties of wheat grown side by side rarely cross, although it has been pretty definitely proved that they sometimes do so. It has not been satisfactorily explained why varieties do not cross under these conditions. Cross-fertilization can readily be accomplished artificially. It has been suggested that it may be due to the stigma being more receptive to the pollen of its own flower than that of other flowers. Rye, a closely allied species to wheat, seems to cross readily. The pollen is often seen floating over a field of rye at the proper season of the year. The anthers are much larger in rye than in wheat, and therefore the pollen more abundant. The abundance of pollen, the ease with which it floats in the air and the time of day at which the flowers open may be factors in this problem. (49)

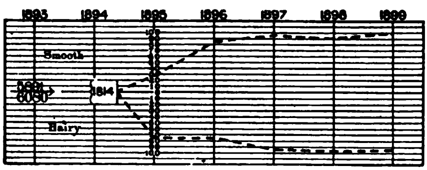
**106. The Law of Cross-Fertilization.**—It is a generally recognized law that cross-fertilization adds vigor to the offspring, and the many devices by which this is accomplished in plants forms a very interesting study. Hays has suggested that Darwin's dictum that nature causes benefits to arise from crossing and abhors self-fertilization may not apply to all plants. He would state the law thus: "Nature abhors a radical change which would require species to cross in much closer or in much more radical relationship than is their long-established habit."

**107. Importance of Crossing as a Method of Improvement.**—Mendel found that hybrid peas selected to one type were soon stable. Mendel's Law worked out formally gives the following results as applied to one characteristic of the artificial hybrids allowed to self-pollinate during a series of years.

**A Study of Artificial Hybrids.**

| Per cent of purity | 1895 | 1896 | 1897 | 1898 | 1899 |
|---|---|---|---|---|---|
| Pure . . . . | 25.00 | 37.5 | 43.75 | 46.875 | 48.4375—96.9 |
| Mixed . . . . | 50.00 | 25.00 | 12.50 | 6.25 | 3.125 |
| Pure . . . . . . | 25.00 | 37.5 | 43.75 | 46.875 | 48.4375—96.9 |

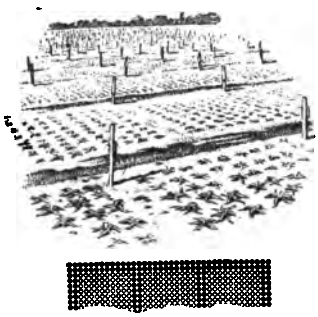
Since wheat hybrids naturally self-pollinate, it would be expected that they would follow the same law, and Spillman found this to be the case. Hays reduced some hybrids to uniform type in four generations. His hybrid varieties based on single mother plants of the fourth generation breed true to the botanical types of the mother plant. Whether the correlated characteristics combined in making up the unit of higher value per acre will continue their united excellence has been questioned. Hays' experience indicates that at least a part of the hybrids which show most vigor in value per acre during the first several years after the hybrids are formed will continue to yield well of good grain. Mendel's results add assurance to the hope that at least part of the complex compound of characters formed in producing a lot of wheat hybrids will remain stable. Hybrids made by Saunders, Hays and others and widely distributed retain their characteristics apparently unchanged.




Graphic expression of the results of an experiment in developing from a single hybrid plant No. 1814 (produced by crossing a plant of Fife with one of Blue Stem), two varieties, one having smooth and the other hairy chaff. (After Hays.)

**108. Method of Finding and Testing New Strains or Varieties.**—The methods of improving wheat by experiment and seed stations now recognize the individual wheat plant as the unit from which selections are made. From whatever source the seed is

obtained, whether from crossing, by selection from a field or simply from the bin, seeds are planted individually in rows any suitable distance apart,—usually four by four inches for spring wheat and five by five for winter wheat. The larger the number of individual plants the better. If any plants are found among those thus grown that possess characteristics desirable to perpetuate, one hundred seeds, more or less, are planted as above indicated in order to determine the ability of the selected plant to transmit its characteristics or in the case of cross-bred varieties by continued selection to fix the type. This group of plants from a single parent has been given the name of centgener.[1] Centgeners of a single strain are raised for three or more years, when, if found promising, all the seed, or as much as may be necessary, of the produce of the centgener, except the best one or more plants, is sown in small plats to test its adaptability under field conditions. If found satisfactory, the seed is rapidly multiplied and distributed among farmers and commercial seed growers. The plants reserved become mothers of centgeners with the hope of obtaining still further improvement.



Method of planting wheat in field nursery of Nebraska Experiment Station. (From photograph by Lyon.)

1 Plant Breeding. By Willet M. Hays. U. S. Dept. of Agr., Div. of Veg. Phys. and Path. Bul. 29 (1901), p. 46.

# V.

## WHEAT.

### I. CLIMATE.

109. **Conditions of Successful Wheat Culture.**—The yield and quality of wheat, and hence its successful growth, agriculturally considered, depend mainly upon these six conditions: (1) climate, (2) soil (including fertilizers), (3) variety, (4) methods of cultivation, (5) liability to disease, and (6) attack of insect enemies.

110. **Effect of Climate Upon Geographical Distribution.**—According to the tenth census seventy per cent of the wheat of the United States was grown where the average January temperature was below freezing; eighty-five per cent was grown where the average July temperature was between seventy and eighty degrees, and sixty-five per cent where the mean annual temperature was between forty-five and fifty-five degrees. Too much weight must not be attached to this, as the soil, particularly in respect to its ease of cultivation, has greatly affected the distribution of wheat. Most of the wheat of the world, however, grows in regions of cold winters, although there are some noted exceptions, as California, Egypt and India. Taking the world at large, and including both spring and winter varieties, wheat has a very wide climatic range. Its range of successful culture, also, seems to be constantly extending northward, whether through climatic adaptation or from other causes seems less clear.

111. **Effect of Climate Upon Quality.**—Localities having widely different climate and soil have their peculiar varieties, which differ somewhat in composition but much more in physi-

cal characters, such as size, plumpness, hardness and color of grain, length and shape of spike and in length of straw. It seems to be quite conclusively demonstrated that these changes are more closely related to climate than to any other factor. (74) Some varieties of wheat, however, such as Fultz, have a very wide distribution.

Those localities which have extremes of temperature and rainfall, especially during the ripening period, generally have the hardest and reddest grains and the highest per cent of nitrogen, but are generally less plump and are smaller in size. Wheat of hot, sunny climates, with moderately dry weather during the latter part of growth, is brighter and makes better quality of flour the world over. The United States is particulary favored in this respect.

112. **Effect of Climate Upon Growth.**—Seelhorst found that a high moisture content in the soil during early growth caused a larger number of spikelets per head, and that a high water content at time of heading increased the number of developed blossoms per spikelet.[1]

A cool, prolonged, but not too wet spring, followed by moderately dry sunny weather during ripening, is most favorable to the largest yield of best quality. The influence of the length of the growing period on the accumulation of plant food and consequently upon yield may be illustrated by assuming that a maximum crop requires twenty-four pounds of nitrates besides those already formed in the soil, and by assuming that throughout the growing season four pounds of nitrates per month are produced by the nitrifying agents in the soil. Six months of growth would be necessary to produce a maximum crop. If climatic conditions should force the crop to maturity in five months, there would not be enough nitrates to produce a full crop, unless the same climatic conditions influenced the production of nitrates in the soil. The loss of nitrates during wet seasons has been

1 Jour. Landw. 48 (1900), No. 2, pp. 165-177, pls. 2. (E. S. R. XIII (1902), 125)

found to be greater and the amount taken up by the wheat smaller.

113. **Accumulation of Soil Constituents at Different Stages of Growth.**—The wheat plant for its best development needs to have its early growth in the cool part of the year. A long period of growth consequent upon cool weather encourages tillering and gives better opportunity to get sufficient plant growth. Adorjan has shown that wheat takes up the greater portion of its food in the early stages of growth, stores it up, and draws upon it later for the development of the grain.[1] (123)

At the Minnesota Station during two years the weight and composition of spring wheat was determined (1) at fifty days when it was eighteen inches high, (2) at sixty-five days when it was fully headed, (3) at eighty-one days when grain was in the milk, (4) at 105 days when wheat was ripe.

At the end of fifty days the plant had produced nearly one-half its dry matter and nearly three-fourths its total mineral matter; when fully headed, sixty-five per cent of its dry matter and eighty-five per cent of its mineral matter. When the grain was in the milk the plant had produced ninety per cent of its dry matter and practically all its mineral matter. Nearly seventy-five per cent of the potash, eighty per cent of the phosphoric acid, and eighty-six per cent of the nitrogen was taken up in the first fifty days. The fiber was formed largely before the plant was fully headed; after the grain was in the milk a slight loss of fiber occurred in the plant. The starch stored up in the seeds was formed mainly during the last half of the period of growth.[2]

114. **Winter Killing.**—In a country of cold winters it is better to have the ground covered continually with snow. Alternate freezing and thawing with the plant exposed to the wind is very destructive to wheat. Winter wheat kills in two ways, by freez-

[1] Jour. Landw. 50 (1902), No. 3, pp. 193-230. (E. S. R. XIV, 436.)

[2] Minn. Bul. 29, pp. 152-160.

ing to death and by being heaved out by alternate freezing and thawing. When the soil is bare, the soil temperature about the roots of the young plant will reach nearly that of the overlying air, while if covered with two inches of snow the soil may, if the low temperature is of short duration, be little if any below freezing

### II. THE SOIL AND ITS AMENDMENTS.

115. **The Choice of Soil.**—The character of the soil affects the yield much more than the quality of the wheat. (74, 111) A large proportion of the wheat is grown in this country upon glaciated drift soil, the controlling reason being the ease of cultivation and adaptation to the use of light machinery.

Throughout the winter wheat region between parallels 38° and 42° N. latitude, within which lies what is known as the "Corn-belt," two general types of drift soil are recognized: (1) clay soils, usually upland, light in color, tenacious in texture, requiring careful tillage, which is generally adapted to wheat and grass crops, and (2) loamy soils, usually lowlands or prairies, dark in color, full of organic matter and friable in texture, generally known as maize land, to which it is especially adapted. This latter is not so well adapted to wheat, because in unfavorable seasons the wheat is apt to winter kill. Where the first type of soil is predominant, wheat, meadows and pastures largely prevail, while where the second type is predominant, maize and oats are the prevailing crops. It is not so much that fair crops of wheat may not be obtained as it is that maize pays better that has brought about this result; although on this soil wheat, as just stated, is very liable to winter kill. On the other hand, on the clay soils maize not only does not do so well, but the grass crop reduces the labor of tillage and helps to maintain the fertility of the soil. There is still a third type of soil to be found in less quantity in river valleys, chocolate in color, less tenacious in texture than the upland clays, being composed of a larger proportion of silt than the clay and less

organic matter than the black soils, but very fertile and equally adapted to either maize or wheat. It is on the first of these three types of soil that fertilizers have been found to be most advantageous. Generally speaking, the increase in yield of wheat on the second and third types of soil has not been sufficient to pay for the cost of the fertilizers.

116. **Effect of Change of Soil on Yield.**—The Indiana Station sent seed of Velvet Chaff grown seven consecutive years to four different counties in the State, and the seed received from the crop was sown the next year at the station alongside the seed retained at the station. There were only slight variations in the yield of wheat from the different localities.[1] The Maryland Station found no material difference between Maryland and Kansas seed with six varieties.[2] Bolley concludes after testing wheat from different parts of North Dakota, representing all kinds of soil, that true varieties under like soil and climatic conditions will approximate a like product without reference to the parent soil.[3] The Nebraska Station found that wheat of the same variety from different sections of the country showed considerable variation in the habit of growth, much to the disadvantage of seed grown east of the Missouri River.[4] At the North Dakota Station the average result of twenty-three tests with home grown seed and with wheat originally from this station but grown at the Minnesota Station from one to nine years, showed a gain of about 2.5 bushels in favor of the home grown seed.[5]

117. **The Use of Fertilizers.**—Nothing has been more clearly demonstrated than the fact that with an increased amount of fertilizers, the yield does not increase proportionately to the quan-

1 Ind. Bul. 41.
2 Md. Bul. 14.
3 E. S. R. VI (1896), 268.
4 Neb. Bul. 72.
5 N. Dak. Rpt. 1900, pp. 59-97.

tity of fertilizer used. It is perfectly obvious that the amount of fertilizer to be applied, whether zero pounds, one hundred pounds, or a thousand pounds, is an economic and therefore a local question. Experiments have shown clearly that some increase in yield will result when fertilizers are applied in proper ways, at proper times, in proper proportions, and in proper condition, to clay soils such as produce much of the winter wheat east of the Mississippi River. Whether the application of a certain quantity of fertilizer will increase the yield sufficient to pay for the cost of application depends upon many factors, some of which are purely local and some can only be determined by trial.

A great many careful trials have been made by experiment stations on their own ground and upon the farms of the citizens of their own respective States. In some cases, the yields have paid good returns for money invested; perhaps in more cases, the value of the increased yield of wheat has not been equal to the cost of the fertilizers used. The longer the land has been under cultivation the more general has the application of fertilizers to wheat become, so that in all of the States east of Illinois large quantities are annually applied for this crop.

118. **Indirect Fertilization.**—Two methods of adding plant food to the soil for wheat are practiced, viz., (1) the direct method and (2) the indirect method.

In the indirect method the plant food may be increased in two ways: (1) by growing wheat in a rotation with other crops which will, by the vegetation which they leave in the soil, or by the culture which the soil receives in growing the crop, increase the available plant food, or in other ways physical and biological, increase the wheat producing capacity of the soil; or (2) by adding fertilizers in the production of other crops in the rotation, the residual effect of which is beneficial to the wheat crop. The best results are obtained in the indirect method when both features are combined in the system of rotation.

119. **Rotations.**—The rotation of crops has been shown to be absolutely essential to the profitable use of commercial fertilizers.[1] Rotations are greatly modified in different localities both by the crop producing capacity of the soil and by economic causes. Wheat is frequently grown because it cannot well be omitted from certain otherwise successful rotations. In many sections for seeding land to timothy and clover, no other crop combines so many advantages.

The five course rotation of maize, oats and wheat, each one year, and timothy and clover two years, is considered standard in many sections. In this rotation stable or farm yard manure is applied to the land before plowing for maize at the rate of about twenty loads per acre. On what is known as maize land, the residual effect of this manuring is usually sufficient to grow a good crop of wheat, provided other conditions, such as climate, rainfall and insect enemies, are not unfavorable. On the more tenacious light colored clay soils, a light application (say twenty-five pounds) of phosphoric acid ($P_2O_5$) is applied at the time of seeding the wheat. A slight modification of the above is the four course rotation of maize, oats, wheat and clover, each one year. A still further modification is the three course rotation of maize, wheat and clover, each one year. This is in regions not well adapted to oats on account of climatic conditions and on soil in which wheat can be successfully raised after maize without plowing. (128) Sometimes mammoth clover is used and treated as a seed crop. One of the most satisfactory rotations in its effect upon the yield of wheat is the three course rotation of potatoes, wheat and clover, each one year. Where stable or farm yard manure is available it is applied to the clover immediately after cutting the second crop in order to stimulate the growth of clover to be plowed under either in the late fall or early spring. In many cases the land is quite heavily fertilized with commercial fertilizers at the time the potatoes are planted.

[1] Ohio Bul. 110 (1899), p. 68.

The wheat is sown after the removal of the potatoes without plowing. The residual effect of the fertilizers combined with the influence of the tillage given the potatoes usually results in increased wheat production.

120. **Carriers of Fertilizing Constituents.** — The results of many experiments with various forms of phosphatic fertilizers seem to indicate clearly that when these are applied to wheat, the carrier or source of the phosphoric acid, whether raw bone meal, undissolved rock phosphate, basic slag, acid phosphate, or tankage, does not materially affect the yield provided the material is finely ground. Nitrate of soda has been found to be the most effective carrier of nitrogen, although the difference in the effectiveness of different carriers of nitrogen is not great when applied to wheat.

121. **Relative Importance of Fertilizing Constituents.**—While field experiments indicate that the relative importance of fertilizing constituents depends upon the soil, throughout the drift area of the United States, phosphoric acid is the only fertilizing ingredient which, when applied singly, has been found generally to increase the yield of wheat. The increase in the yield of straw has usually been greater than the increase in grain. (53) For this reason, the increased appearance of the crop is generally greater than the increased yield of grain. The influence of fertilizers upon the seeding of timothy and clover when it accompanies the seeding of the wheat is often decidedly favorable. Neither nitrogen nor potash when used alone produces generally any marked influence on the yield, but both, and nitrogen especially when applied with phosphoric acid in proper proportions, appear to exert a favorable influence. The Ohio Station has found that a complete fertilizer, containing all three constituents, has produced a much larger total increase than the sum of the increase produced by the constituents used separately.[1] The same idea is expressed in the results obtained

[1] Ohio Bul. 110 (1899), p. 68.

in a five year rotation of maize, oats, wheat, each one year, and clover and timothy two years, fertilizer being applied to each of the grain crops:

> "When phosphoric acid has been applied alone in superphosphate, 20 per cent of the quantity applied in the fertilizer has been recovered in the crop. When phosphoric acid has been reinforced with potash, there has been a recovery of 27 per cent of the former. When phosphoric acid has been reinforced with nitrogen instead of potash the recovery has reached 38 per cent of the phosphoric acid applied, and when both potash and nitrogen have been added, the recovery of the phosphoric acid has amounted to 46 to 50 per cent."[1]

Wheat does not appear to be benefited directly by the application of lime. If the soil needs liming, it is best applied to the land prior to planting it to maize.

**122. Amount of Fertilizers.**—A standard application of fertilizer may be said to be one that furnishes from ten to twenty pounds each of ammonia and potash and from thirty to sixty pounds of phosphoric acid. This can be obtained by applying from 250 to 500 pounds of a commercial fertilizer containing four per cent of ammonia, twelve per cent of available phosphoric acid, and four per cent of potash. This is often referred to as a 4-12-4 fertilizer and is a grade that usually can be found on the market.

The ratio of phosphoric acid to nitrogen and potash should be varied somewhat with state of fertility. With soil quite exhausted through continuous culture the proportion of nitrogen and potash to phosphoric acid should be increased, while with land of higher fertility and with favorable rotation, nitrogen and potash may be reduced. The above figures are at best only general averages.

When it is necessary to apply lime to wheat land, an amount equal to 1,000 to 1,500 pounds of quick or freshly burned lime ($CaO$) may be applied. When it is water-slaked it will have increased in weight thirty-two per cent ($CaO : Ca(HO)_2 :: 100 : 132$).

1 Ohio Bul. 110 (1899), p. 57.

**123. Time and Manner of Applying Commercial Fertilizers.**—Commercial fertilizers are applied to wheat lands by sowing broadcast just in front of the wheat drill or by applying at the same time the wheat is drilled by a fertilizer attachment. The latter method is much to be preferred. In some cases an additional application of nitrogen is made to winter wheat by sowing nitrate of soda broadcast in the spring. At the experiment stations it has been customary to apply one-fourth of the nitrogen in the fall, often in the form of dried blood, and the rest of the nitrogen in the spring in the form of nitrate of soda, on the theory that if all the nitrogen is applied in the fall in a soluble form, much of it would be lost through drainage during the winter. Where nitrogen is applied in the spring, care should be taken to apply it before the wheat plant has made much growth. (113)

In case lime is used, it should be spread upon the plowed land three or four days before seeding, immediately harrowed in and allowed to remain until all lumps which may be present have slaked, when the ground should be stirred again, preferably with a spring tooth harrow.

**124. Farm Manure.**—Farm manure is usually applied to some other crop in the rotation, as maize, rather than directly to the wheat. If applied directly to wheat land, better results will be obtained by applying 200 tons to twenty acres of wheat than by applying the same amount to ten acres. If the preceding crop has been oats, the manure should be spread as soon as possible after the oats are cut and the land plowed. It is desirable that the manure should be well rotted, where rainfall is liable to be deficient. Beginning with a virgin soil, the Central Experiment Farm has found, however, after sixteen years that fresh and well-rotted manure applied in equal weights gave equal yields of grain and straw, while barnyard manure gave considerably higher yields than any form of commercial fertilizers, and about twice the yield of plots not

fertilized.[1] Farm manure may be applied to the land after the wheat is sown, if well rotted, preferably with a manure spreader, if the condition of the land is such as not to be cut up too much with the spreader. Experiments have shown that a ton of stall manure will produce a larger return of wheat than a ton of yard manure.[2]

Farm manure does not produce as large returns for the fertilizing constituents contained as commercial fertilizers when applied to wheat; nevertheless its lower cost often makes its use profitable. Where there is a limited quantity of farm manure or where both farm manure and commercial fertilizers are used, the best practice usually is to apply the farm manure to land for maize and apply the commercial fertilizers, if deemed desirable, to the land for wheat.

125. **Mulching.**—Mulching wheat with straw or other material for the purpose of winter protection has not been generally practiced. The Ohio Station[3] has tested the value of mulching for a series of years, and has found no practical benefit from the use of a mulch. In severe seasons the benefit has been very slight, while in mild seasons the mulch has usually been harmful. A heavy mulch was more harmful than a light one. The Tennessee Station[4] obtained about five per cent less yield from a lightly mulched plat than from one which was not mulched.

In exposed situations and localities where there is little snow upon the ground, a light mulch may be beneficial to the wheat. But where there is considerable snow and the temperature more uniform the mulch is pretty certain to do more injury than good. Mulching, however, must not be confused with a top dressing of stable manure for the purpose of adding fertility to the soil.

[1] Can. Expt. Farms Rpt. 1903, p. 24.

[2] Ohio Bul. 110 (1899), p. 52.

[3] Ohio Bul. 82.

[4] Tenn. Vol. III, Bul. 2.

The value of the latter will depend largely upon the needs of the soil and the character of the manure used.

### III. CULTURAL METHODS.

**126. Time of Plowing.**—It is generally conceded to be good practice to plow for winter wheat as early as practicable after the previous crop has been removed. This allows the soil to become compact before the seed is sown, prevents weeds from going to seed, and conserves the soil moisture by preventing the growth of vegetation, by the pulverization of the surface soil and by enabling more of the rainfall to be absorbed. In this connection the pulverization of the surface after each heavy rainfall, preferably with a spring tooth harrow, is extremely desirable in order to prevent surface evaporation.

The experiment made by the Oklahoma Station[1] is a fair illustration of what may be expected in the drier climates or the drier seasons of the more humid sections. Plats were plowed on July 19th, August 15th and September 11th. The early plowed plat turned up moist and mellow; the medium plowed somewhat dry and lumpy, while the late plowed plat was weedy, turned up lumpy and was dry to the full depth of plowing. Disking, harrowing and rolling was necessary to the extent that it was estimated that about eight times as much labor was put on it as would have been necessary had the ground been plowed when moist. All sections were seeded September 15th. In the early plowed plat germination was prompt and growth good. On the late plowed portion many plants suffered from lack of moisture; the following summer the crop matured later, was more seriously affected by blight, and the grain was more shrivelled. The following yields were obtained:

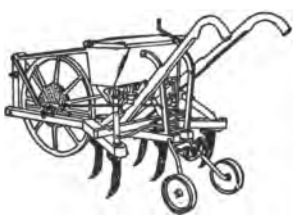
| Date of plowing | Yield per acre, bu. |
|---|---|
| July 19 | 31.3 |
| August 15 | 23.5 |
| September 11 | 15.3 |

1 Okla. Bul. 47 (1900), pp. 26-48.

The results of Utah, North Dakota and Minnesota in plowing in fall and spring for spring wheat are only slightly in favor of the fall plowing so far as yield is concerned, but early fall plowing is generally advocated by these stations in the interest of weed and insect destruction and more economical farm management. In Manitoba, spring plowing has given better results than fall plowing, while summer fallowing has given better results than either.[1]

127. **Depth of Plowing.**—Generally speaking, plowing less than four inches or more than eight inches deep has not been found desirable. Within and even beyond these extremes the depth of plowing should vary with the character of the soil and the subsoil, but no specific rules can be laid down. In all cases the variation in yield due to depth of plowing has been slight. Subsoiling has not been found economical by any experiment station reporting results, and in some cases the yield has been reduced.

128. **Preparing Seed Bed Without Plowing.**—It is a common practice on the friable loam soils of the Mississippi Valley to drill winter wheat without plowing on land which has just produced a crop of maize. In many instances the wheat is drilled in the standing maize without any previous preparation, by drawing a five-hoe drill between the rows. Where the land is weedy the drill is sometimes preceded by a harrow drawn by one horse. In this case the soil has the proper surface pulverization from the cultivation of the maize and is compact below. Afterward, at the proper time, the maize is husked. In the winter or spring, when the ground and stalks are frozen, the



Five-hoe grain drill. Hoes may be adjusted to different widths.

[1] Can. Expt. Farms Rpt. 1899.

stalks are broken off by drawing a heavy drag over the surface—an old railroad rail being frequently used for this purpose. In many cases—and this practice is growing—the maize is cut and shocked before the proper time to sow the wheat. Then the wheat is sown as in the standing maize, or the more common practice on the heavier soils is to cut out the maize stubs with a disk harrow and harrow down with some suitable levelling instrument, preferably a spring tooth harrow. These methods make it possible to follow maize with winter wheat and the expense of putting in the wheat is small. It is thought also that the stalks are some protection to the wheat at times in preventing the snow from drifting off the wheat. The effect of this practice upon yield is hardly subject to determination experimentally except where the maize is cut before seeding. The experiments which have been made under the latter conditions indicate that the relative yield will depend upon the character of the soil. Where the soil is mellow and light, it should not be plowed; where it is heavy clay, plowing will be found desirable. In the latter case rotation is generally such that wheat does not follow maize.

In the spring wheat region, land that has previously been in oats or wheat is sometimes prepared without plowing, by using a disk harrow or similar instrument. Minnesota [1] found disking as good as plowing on burned stubble field; while North Dakota found that plowing gave the best results.[2] Among the objects to be attained in preparing the seed bed are the prevention of the growth of weeds and the conservation of the soil moisture, and whichever method most nearly accomplishes these results will probably be best. Plowing is not necessary for root penetration in the friable soils of the spring wheat region.

129. **Time of Sowing.** — The proper time to sow wheat depends upon climatic conditions, the fertility of the soil, the

[1] Minn. Bul. 46.

[2] N. Dak. Bul. 10.

preparation of the seed bed, the liability to injury from the Hessian fly, and perhaps slightly upon variety.

It is possible to sow later as we go south, and necessary to sow earlier as we go north. When sown too late, the wheat has not sufficient vitality to stand the cold weather. When sown too early, its growth is so rank and succulent as to be injured by freezing. Experiments indicate the best average time of seeding in Ohio, Indiana and Illinois on the fortieth parallel to be about two weeks earlier than in Tennessee upon the thirty-sixth parallel; while the results at Columbus, Ohio, on the fortieth parallel and Wooster on the forty-first parallel indicate a difference of about one week. Doubtless differences in the fertility of the soil as well as temperature and rainfall have affected the results.

In some localities, early sown wheat is subject to attack from the Hessian fly. When such attacks are imminent, they may be avoided, by concerted action among the farmers of a neighborhood, by later sowing, especially if delayed until there is a killing frost, and also by sowing early some strips of wheat where the Hessian flies will congregate, and may be destroyed by plowing under the wheat. Generally speaking, delay until killing frosts occur is too late for the best growth of wheat in the fall, except on fertile soils. Where it is necessary, therefore, to delay the seeding of wheat to escape the ravages of the Hessian fly, the seed bed should be put in the best possible condition both as to fertility and physical properties.

The results of the various stations show clearly that there is no best time for any given locality. Some seasons quite early sowing gave the largest yield, while other seasons late seeding gave the best results. Very much depends upon the season prior to and after seeding. It may be said as a general rule, although late sowing is often as good as early sowing, it is seldom better, while early sowing is often better than late sowing. The more fertile the soil, the later the

seeding may be done with safety, as the rich soil produces the growth needed in a shorter time. Wheat often suffers in the fall from lack of rainfall. It is seldom injured from an excess of rainfall. As the time and manner of preparing the seed bed materially affects the moisture of the soil, the preparation of the seed bed may have a decided influence upon the time of sowing. The earlier and better the seed bed is prepared the later the seeding is permissible. On the fortieth parallel at an altitude of 500 to 1,000 feet, winter wheat should be sown generally about September 20th, with variations of a week either way, depending upon various factors indicated above.

While obviously not as many factors enter into the time of seeding of spring wheat as winter wheat, climatic and seasonal variations necessitate as wide variations perhaps in the former as in the latter. It may be laid down as a general rule that spring wheat should be sown as early as the ground can be got in fit condition for seeding. In both North Dakota and Minnesota the earlier sown spring wheats gave best results, while in Utah a medium date gave the best yields. Delay of two or more weeks in sowing caused marked losses where conditions were those of Ontario and Quebec. In other provinces the loss from delay in sowing was less marked. Seeding should be finished by May 1st in Ontario and Quebec, and in other provinces from May 15th to 25th.[1]

130. **Depth of Sowing.**—This will vary with the kind of soil, the moisture, and the levelness and the firmness of the seed bed. Wheat may be sown deeper in a sandy soil than in a clay soil. It is necessary to sow deeper in a dry than in a wet soil. Variations in rainfall often materially modify the depth of seeding. It is reasonably well established that, under ordinary conditions, the nearer the seed is covered with one inch of moist soil, the better. An uneven and cloddy soil would require that some be planted deeper than is desirable

1 Cent. Expt. Farm, Canada, Bul. 21.

in order that all may be covered. A summary of the work of eight stations, mostly in the Mississippi and Ohio Valleys, aggregating twenty years' results, shows that in some instances four inches was at least as good as shallower depth, but in most instances one to three inches gave the best results, and indicates that usually it is not safe to go beyond these extremes.

131. **Drilling Compared with Broadcasting.** — Stations of thirteen States have made experiments to compare drilling wheat with broadcasting it. The number of years' trial at a station varied from one to nine years and aggregate thirty-three years. Only two stations (Iowa and South Carolina) report, as the result of one year's trial, in favor of broadcasting. While in individual years broadcasting has produced the best results, at other stations the average of two or more years was in favor of drilling whether for fall or spring seeding. For fall seeding, the Ohio Station found as the result of nine years' trial two bushels in favor of drilling; Indiana in four years' trial reports eight bushels gain, and Kentucky in three years' trial reports four bushels gain. For spring seeding, Minnesota in three years' trial reports two bushels gain; North Dakota in two years' trial reports five bushels gain, and South Dakota in two years' trial reports two bushels gain. While these differences are not great, they generally amply pay for any extra cost of drilling, which is almost the universal practice for fall seeding.

A number of reasons may be given for this practice, not all of which, however, will apply in any given locality. The wheat is more uniformly distributed and covered and is sown at a more even depth. Quick germination is insured by having the seed in moist soil. It is believed also to be less easily winter killed either by freezing or heaving. The drill makes little furrows in which the snow lodges and is prevented from being blown away. It has been abundantly proved that the amount of snow held in the furrows is sufficient to modify the temperature

of the soil considerably. The wheat is less likely to be heaved out from freezing and thawing. The soil at the bottom of the furrow offers greater resistance to the heaving than does that at the top of the ridge. The movement of the soil will take place at the point of least resistance, which will be at the top of the ridge, thus increasing the chances of the plant at the bottom of the furrow to remain undisturbed. At the same time the loosened soil, aided by the rains, tends to fall into the furrows and thus further protect the plant. Just how much effect this has one year with another is not known, but in some trials during one year by the writer, where the furrows were obliterated by rolling, the yield was not materially affected.

In the spring wheat districts, the winds tend to lay bare the seeds when broadcasted, while drilling rather tends to deepen the covering by partially filling up the furrows. Practice seems to show also that weeds are less troublesome in spring wheat when drilling is practiced, doubtless because it insures quicker germination of the wheat.

132. **Quantity of Seed per Acre.**—The quantity of seed to be sown per acre will vary with the character of the soil, climate, time of seeding, seed bed, size, quality and variety of seed, and method of seeding. If sown early, less would be required than when sown late, because each plant would become larger, tiller more, and thus cover more ground. If the seed bed is well prepared, and the vitality of the seed good, a larger percentage of the seed will grow than if the seed bed and seed are poor. Fertile soil requires a less number of plants per acre than a poor soil because each plant tillers more and grows larger and thus occupies more room. A bushel of one variety may contain three times as many grains as another. A variety which tillers profusely could be sown thinner than one that does not. If drilled, a less quantity could be sown than if sown broadcast.

The yield will not be at all in proportion to seed sown. The wheat plant adjusts itself to its surroundings. If sown

thickly, it tillers but little and produces but few spikes per plant. If sown thinly, it stools more and the spikes are larger, often sufficiently to counterbalance the thin seeding.

In climates where the winters are uniformly mild, much thinner seeding may be practiced than where the winters are severe. The fact seems to be that when the winters are mild the plant largely adjusts itself to its surroundings, so that it makes but little difference how much seed is sown within reasonable limits, but when the winter is severe and the wheat partly killed, if the wheat is sown thickly there may still be wheat enough left to raise a fair crop.

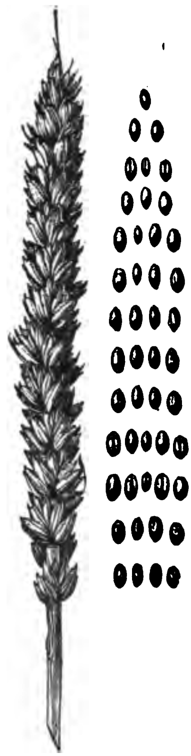
The Statistician of the United States Department of Agriculture estimates the average quantity of winter wheat sown at 1 3-8 bushels per acre, and of spring wheat at 1 1-2 bushels per acre. Professor Brewer found by means of circular letters sent to representative farmers throughout the country that the amount sown in the Middle Atlantic States was seven to nine pecks, in the Mississippi and Ohio Valleys six to eight pecks, and in California three to eight pecks, the smaller amount being used in the drier regions.

Experiments have been carried on in the experiment stations of Ohio, Kentucky, Indiana, Illinois, Kansas and Oklahoma for periods ranging from three to eleven years, aggregating thirty-three years' trials. In no case was the largest average yield at any of these stations made with less than six pecks of seed per acre, or more than eight pecks. Two stations report in favor of six pecks, one in favor of seven pecks, and three in favor of eight pecks. The Ohio Station not only reports in favor of eight pecks, but also states that with the thicker seeding the weight per bushel is greater, and consequently the quality of seed better.[1] In some cases, on moderately fertile soil, better results were obtained with nine to ten pecks. In experiments of all the stations the variation in yield between five and

1 Ohio Bul. 118.

eight pecks was not usually large. In ordinary practice the tendency seems to be to use too little rather than too much seed.

133. **Influence of Size of Seed.**—Ontario Agricultural College, by selecting seed of winter and spring wheat, oats, barley and peas during five to eight years, found the average yield of grain and straw and the weight of grain per measured bushel to be in favor of large, plump seed as compared with medium-sized or small seed.[1] Indiana found an average gain during three years of 2.5 bushels in favor of large seed. Kansas Station found on an average of four years a slightly higher yield from wheat with high weight per bushel.[2] Nebraska Station found that large heavy seed gave much better yields than unselected seed.[3] North Dakota Station concludes as the result of four years' tests that perfect grains of large size and greatest weight produce better plants than perfect grains of smaller size and weight, even if the grains come from the same spike.[4] A summary of nine years' results at the Ohio Station with selected seed, second grade and unscreened seed, shows that neither the quantity nor the quality of the crop was varied by the seed used.[5] No marked difference was obtained at Penn-



Spike of wheat grown in New South Wales, one-half natural size, showing relative size of grains as extracted from spikelets on one side only of the spike (After Cobb.)

[1] Ont. Agr. Col. Expt. Farms Rpt. 1901, pp. 82-111.

[2] Kan. Bul. 59, pp. 89-105.

[3] Neb. Bul. 72.

[4] N. Dak. Rpt. 1901, pp. 30-44.

[5] Ohio Bul. 29, p. 25.

sylvania Station between seed from threshing machines and that selected by hand.[1] At the Tennessee Station, with two varieties, while in general the yield was in favor of the larger seed, it was not uniformly so. The evidence showed that the largest grains usually came from the largest spikes, but the seed from the largest spikes did not always give the largest yield.[2] Middleton, at the University College of Wales, obtained nearly double the yield of wheat from large seed than from small seed.[3] Lubanski has experimented in Russia with winter wheat, barley, oats and sugar beets, and finds the yield, and to some extent the quality, influenced in favor of large seed.[4] Desprez, at Grignon, France, has conducted experiments with several varieties for several years, the general results being in favor of the large seed. Different weights of seed were sown with each variety, but the same weights of large and small seed were sown: thus no two plats received the same number of seeds.[5] In 1900, Deherain reports from the same station but slightly better results from large seed.[6] Cobb reports tests of various sizes of wheat grains and concludes that the superior yield from large, plump grain is sufficient to justify the cost of first-class cleaning machinery.[7]

The results of foreign experiments are rather uniformly in favor of large seed: some experiments showing rather striking results. A careful analysis of all American experiments appears to show that where large and small seed are obtained by the use of the ordinary fanning mill the yield has been only slightly if at all increased on account of the seed, while apparently, where greater care is taken in the selection, a moderate increase

1 Penn. Rpt. 1893, p. 112.

2 Tenn. Bul. Vol. XIV, No. 2 (1901), pp. 42-47.

3 University College of Wales Rpt. 1899, pp. 68-70.

4 Selsk. Khoz. i Lyesov. 200 (1901), Mar., pp. 611-617. (E. S. R. XIV, 432.)

5 Jour. Agr. Prat. 2 (1897), No. 37, pp. 416-420.

6 Ann. Agron. 26 (1900), No. 1, pp. 20-23. (E. S. R. XII, 233.)

7 Seed Wheat, pp. 1-60: Sidney, 1903.

in the yield has been obtained. In a number of experiments the influence of the number of seeds per acre has not been eliminated.

If the grains of the spikelets of wheat be designated by numbers according to the distance from the spikelet, it has been found that grains occupying the second place are the heaviest; that those in the first and the third place are about equal in weight; while grains in the fourth and the fifth place, if any, are still lighter. It is also found that of grains occupying the same relative position, those on the lower half of the spike are the larger. The following table gives results with two varieties of wheat:[1]

| | Martin Amber | | Spalding Prolific | |
|---|---|---|---|---|
| Place in spikelet | Below middle mg. | Above middle mg. | Below middle mg. | Above middle mg. |
| 1 | 59.8 | 52.3 | 60.6 | 52.4 |
| 2 | 66.6 | 57.2 | 68.4 | 60.7 |
| 3 | 56.1 | 47.2 | 62.6 | 52.9 |
| 4 | 32.1 | .... | 51.2 | 30.6 |
| 5 | .... | .... | 45.6 | .... |

It would thus appear that small and large grains come from the same plant, varying in size because of their position, as do the grains of maize on the ear. If the plant and not the individual seed is the unit of reproduction, small seeds from productive plants will be better than large seeds from unproductive plants, provided productivity is due to heredity and not to environment, except in so far as large seeds may give the plant a more vigorous start in life. (43) It has been shown, however, that on an average, the larger spikes contain the larger grains, so that in selecting the larger grains the larger number of them would come from the larger spikes.[2]

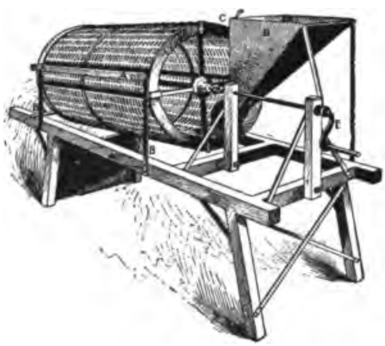
**134. Treatment of Seed.**—Before sowing, the seed should be carefully screened in a fanning mill, or wheat grader, or

1 Kurt Rumker: Jour. of Landw. 38 (1890), p. 309.

2 Seed Wheat, pp. 1-60: Sidney, 1903.

preferably both, not only to eliminate all small and undeveloped grains, but to remove weed seeds and diseased grains, if any.

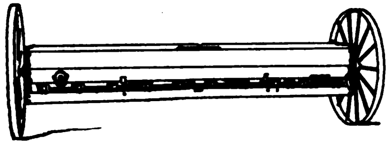
If seed comes from plants that have been affected with stinking smut (149), the seed should be immersed in cold water and stirred, when the smut balls will rise to the surface and can be skimmed off. The seed should then be sprinkled or immersed thirty minutes in a solution of formalin mixed at the rate of fifty gallons of water to one pound of formalin (forty per cent solution of formaldehyde). Blue stone solution or hot water may be used in place of the formalin. (149) In case wheat has been affected with the loose smut the wheat may be given the modified hot water treatment. (148) It is necessary in such case to use one-half more seed to replace seed injured by treatment. Since loose smut is usually not very destructive, it will probably be rarely advisable to resort to treatment of seed for loose smut.



A seed wheat grader suitable for use by wheat growers. Wheat is sorted according to size of grains and not according to specific gravity. The screen is a cylinder of perforated sheet metal, actuated by the crank E. A brush, AA, an important feature, is held against the screen by the springs, BB. Meshes ranging from two to three millimeters may be used; where only one size is supplied, 2.5 millimeters (one-tenth inch) should be used for American wheat. (After Cobb.)

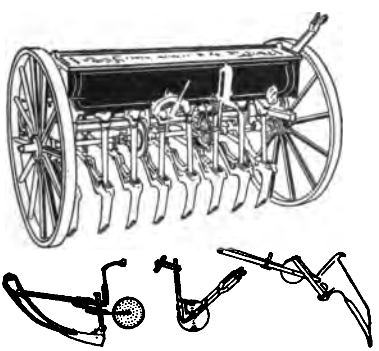
135. **Wheat Seeding Machinery.**—For broadcasting small areas, the hand grass seeder will do satisfactory work when it is not too windy. The usual horse broadcast seeder is not unlike the wheat drill, except the wheat is scattered directly from the hopper onto the surface of the ground instead of being conveyed by means of hoes underground. Standard widths are eight,

eleven and fourteen feet. The wheat drill is made in three general forms: (1) hoe drills, (2) disk drills, and (3) drills with runners or shoes. The drill with runners also usually has a wheel behind each runner which is designed to press the earth firmly about the seed. Wheels are also sometimes used on disk drills. Where these wheels are used they are known as press drills.



The broadcast grain seeder.

The first form of drill is made with shovels, called hoes, which open the ground and permit the seed to be introduced in a stream into the soil behind each hoe. The hoe drills will operate under a larger number of conditions, but are heavy of draft and are liable to clog when the soil contains much rubbish. The disk drills draw easier, and are not so liable to be clogged with rubbish, but are not so well adapted to stony or hilly land and will not work so well in wet soil. The drills with runners have not been extensively employed. The hoes are made so as to run either seven or eight inches apart. When the hoes are seven inches apart, nine, ten and eleven hoes, and when eight inches apart, six and eight hoes, are standard sizes.



Grain drill. Three methods employed in opening the soil for the introduction of the seed are shown below.

There is no evidence to show that one width of seeding is better than another. Eight-inch drills are less liable to clog

with rubbish than seven-inch, although the zigzag arrangement on both sizes lessens the importance of this difference.

Wheat drills may be purchased with and without grass seeder attached, and with and without fertilizer drill. The grass seeder scatters the seed broadcast either in front or behind the drills as preferred, while the fertilizer is conveyed into the ground by the same channel as the grain. There are a number of different methods of conveying the grain and the fertilizers from their respective hoppers, most of which are satisfactory. Those forms which vary the amount sown by means of variation in the sizes of cog wheels used are probably the best. These drills are usually intended to sow the seeds of all ordinary field crops.

The hand seeder.

136. **Cultivation.**—The cultivation of wheat much as we cultivate maize in this country was formerly vigorously advocated and somewhat practiced in England. This practice has never been common in the United States, and only one station (Alabama) out of seven which have reported trials has found it beneficial as compared with the usual method. In most cases it has been found decidedly detrimental. A number of stations have reported in favor of harrowing wheat drilled in the ordinary manner one or two weeks after seeding. The Ohio Station reports that harrowing winter wheat in the spring did no harm.

137. **Rolling.**—Winter wheat may be rolled in the spring, when there is much heaving of soil, in order to pack the soil about the roots. The cost of thus smoothing the surface may often be repaid by the increased facility with which the crop can be harvested. When grass seed is sown with the grain, rolling should never be neglected.

# VI.

## WHEAT.

### I. WEEDS, FUNGOUS DISEASES AND INSECT ENEMIES.

138. **Weeds.**—A great variety of weeds occur in the wheat field which may reduce the yield or injuriously affect the quality of the grain. In general they are to be avoided by those conditions which best promote the growth of wheat, and by sowing wheat that is free from foreign seeds.

There are a few species of plants that are so associated with the raising of wheat as to deserve special mention. The presence of a considerable quantity of any of these weeds in a wheat field must, of course, somewhat reduce the yield of wheat. But the principal injury, perhaps, is in the reduction in the quality of the grain, due to the presence of the weed seeds.

(1) Chess or cheat (*Bromus secalinus* L.)
(2) Darnel (*Lolium temulentum* L.)
(3) Cockle (*Agrostemma githago* L.)
(4) Wild garlic (*Allium vineale* L.)
(5) Wheat-thief (*Lithospermum arvense* L.)

139. CHESS.—Chess belongs to a different tribe (*Festuceae*) of the grass family from that of wheat (*Hordeae*), which includes, also, some of our best known pasture and meadow grasses. It is an annual and so closely resembles wheat while young as not to be distinguished from it by the ordinary observer. It will stand more cold than the wheat plant, is not attacked by insects especially injurious to wheat, is a less vigorous grower than the wheat plant, but is much more prolific than wheat when its development is not prevented by the growth of the more vigorous wheat plant. The author sowed one pound of chess on one-twentieth of an acre and reaped ninety-nine pounds of seed. A single plant has been known to produce 3,000 seeds. The seeds which adhere to the paleae are so small that a pound of chess may contain as many seeds as a bushel of wheat. Experiment has shown that chess seed will grow when sown, and that the young plants can be distinguished from wheat plants. It has also been shown that when wheat only is sown in clean ground only wheat is obtained; that when wheat and chess are sown both wheat and chess

are obtained, and when chess only is sown only chess is obtained. It has been shown further that in order to obtain seed from chess, chess must be sown the preceding fall. When sown in the spring it does not produce seed for the same reason that winter rye and winter wheat do not. It is not found, therefore, in any but fall sown crops, and is less abundant in rye than wheat, because of the greater hardiness of rye as compared with wheat. The above habits are sufficient to explain the abundant development of this plant in wheat which has been injured by winter killing or by the Hessian fly when the sowing of clean seed has not been continuously practiced. The introduction of chess seed in the grain seriously injures its market value, as the chess must be removed before the wheat is ground. The machinery for this purpose in large milling establishments has reached great perfection. Hackel says that flour containing an admixture of chess will be dark colored, remain moist and is narcotic.[1] Chess can be removed rather readily from the seed wheat by the ordinary fanning mills. When wheat is treated for smut, if the grains are stirred in the solution, any remaining chess seeds will come to the surface and can be skimmed off.

Chess. (One-fourth natural size.)

140. Darnel.—Darnel belongs to the same tribe of grasses as wheat, to the same genus as perennial and Italian rye grass. Unlike these grasses, however, it is an annual. It occurs in grain crops of Europe and is also reported occurring in wheat fields of California, where it is known as chess. This plant is supposed to be the "tares" spoken of in the Bible. Like chess it is said to contain a narcotic principle which causes eruptions, trembling and confusion of sight in man, and in flesh-eating animals, and very strongly in rabbits, but does not affect swine, horned cattle or ducks.[2] Darnel may be removed from wheat intended for seed by the same method as chess.

Cockle. (One-fourth natural size)

1 The True Grasses, p. 168.

2 Ibid, p. 173.

141. COCKLE.—Cockle is a widely and anciently distributed weed of the wheat field, belonging to the pink family (*Caryophyllaceae*). It grows from one to two feet high and is readily distinguished by its large pink blossom. Its seeds are black, angular, kidney-shaped, one-half to one-eighth of an inch across, marked with spiny reticulations arranged in rows around the curved side of the seeds. They are quite injurious to flour, and as they are readily seen in the grain, reduce the commercial value of the wheat. They are so near the size and weight of wheat grains as to be removed with difficulty. They may remain in the ground several years without germinating. As the plant is rather conspicuous and its number usually not relatively large, they may be pulled from the growing wheat.


Wild garlic. (One-fourth natural size.)

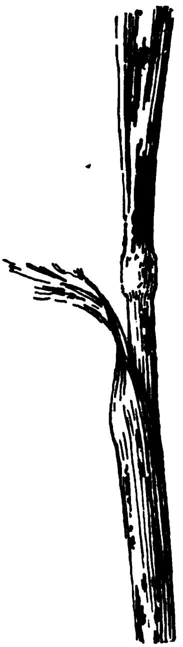
142. WILD GARLIC.—This weed is sometimes found in the wheat fields of eastern United States. It grows one to three feet high and bears a cluster of bulblets in place of seed. When these bulblets are ground with the wheat the flour is spoiled. Careful screening will remove the bulblets from the wheat. If the land is badly infested, it should be put into cultivated crops for at least two years.

Wheat-thief.
B, seed enlarged.
(After Selby.)

143. WHEAT-THIEF.—This winter annual is also known as bastard alkanet, corn gromwell, redroot, pigeonweed. It grows six to twelve inches high and has narrow rough hairy leaves. It bears a large number of inconspicuous whitish flowers in a leaf cluster in March and April. The seeds are hard and stony, dark, one-tenth of an inch long, roughened, conical with a narrow base, and borne in fours in the axils of the leaves. The plant is very hard to destroy, without destroying the wheat crop, which may in some cases be advisable. It is probably less of a pest to the wheat than it is to the subsequent meadows. Badly infested fields should be put into cultivated crops.

144. WILD MUSTARD.—There are two mustards, black mustard (*Brassica nigra*, (L.) Koch) and wild mustard or charlock (*B. sinapistrum* L.) found growing in spring

sown cereals, of which the wild mustard is the most common. It is so common in spring wheat that the seed has become a by-product of flouring mills. The mustards are tall prickly plants with large leaves and bright yellow flowers. The wild mustard is distinguished from the black mustard on account of its long knotted pod being a stout two-edged beak. Seeds are dark brown to black, commonly spherical, one-twentieth of an inch in diameter, slightly granular-roughed. It has been found that by spraying wheat or oat fields with a three per cent solution of copper sulphate (about ten pounds to the barrel, or forty gallons, of water) at the rate of fifty gallons of solution to the acre, the mustard may be killed without injury to the cereal.[1] The treatment is most effective if made in clear bright weather.


The black rust on wheat.

145. **Fungous Diseases.** — The more important fungi which attack the wheat plant are given below:

(1) Rust (*Puccinia graminis* Pers. and *P. rubigo-vera* (D C.) )

(2) Wheat scab (*Fusarium roseum* Lk.)

(3) Loose smut (*Ustilago tritici* Jensen.)

(4) Stinking smut (*Tilletia foetens* B. & C.)

Another little studied fungus causes rather conspicuous dark spots upon the glumes of wheat, and has been given the name of "glume spot." There is no known remedy.

146. Rust.—The rusts of wheat in the United States belong to two closely allied species, black stem rust and orange leaf rust, only the latter of which it is believed can pass the winter in the wheat plant.[2] There are two stages of rust found on the wheat plant: (1) the red rust, caused by one-celled spherical *uredospores*, which commonly does not survive the winter, and (2) the black rust, caused by elongated two-celled *teleutospores*, which may pass the winter upon the ripened plant. It is believed that the rust plant may enter the wheat plant at the time of germination, or later if opportunity offers.

The loss caused from rust is difficult to estimate, but it is undoubtedly very large. It is encouraged by hot moist weather during the ripening period. There is no

[1] Cornell Bul. 216 (1904), p. 107.

[2] *P. rubigo-vera* (D C.)

known remedy. A great deal of study has been given to the discovery or production of rust proof varieties of wheat, with as yet little if any success.

147. WHEAT SCAB.—The scab fungus is believed to be the conidial stage of a fungus which in its ascigerous stage is called *Gibberella saubinettii* (Mont.) Sacc. The fungus attacks the glumes, causing dead sections of the spike, whose brown color is in striking contrast with the green healthy glumes. At times the whole spike is destroyed. It may be identified by the pink incrustations at the base of the dead glumes and covering the rachis.

Usually the losses are inconsiderable, although under conditions favorable to the fungus, it may amount to ten per cent or more. There is no remedy known, but where wheat is to follow scabby wheat the burning of the stubble has been recommended.[1]

Wheat spike with scab: Upper portion has been destroyed by the pink fungus. One-half natural size. (After Selby.)

148. LOOSE SMUT.—This fungus belongs to the same genus as the smut so commonly found on maize. The spores adhering to the grain germinate and enter the young wheat plant through the sheath of the first leaf. The fungus grows within the wheat plant without external manifestation until the wheat plant is about to flower, when the whole spike except the rachis is reduced to a mass of black smut spores.

The loss from loose smut is rarely large, although as high as eight per cent has been reported.[2] The remedy is known as the modified hot water treatment and is as follows:

Soak the seed grain for four hours in cold water, let stand for four hours more in the wet sacks, then immerse for five minutes in water at a temperature of 133° F.; then dry and sow.[3] Since this treatment injures the germinating power of the seed, one-half more seed per acre is required. The purchase of non-infected seed is also to be recommended.

149. STINKING SMUT.—Stinking smut is closely allied to the loose smut of wheat, in form and habit, although differing from it in the character and extent of its injury. It affects only the grains, which are considerably enlarged, the interior being converted into blackish, offensive smelling masses of spores, which, when they find their way into the flour, make it unfit for food. The glumes being unaffected, the disease often escapes observation until after the grain is threshed. Losses from this smut are rather general and often considerable, amounting in some instances to at least forty per cent, which, practically speaking, ruins the crop.

Any one of the following remedies has been found effective:

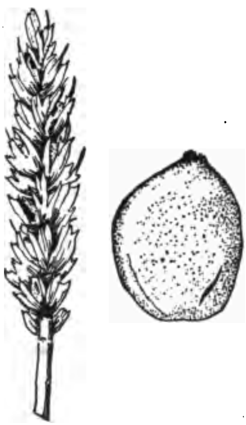
(1) Hot water: Place seed in any bag or basket which will readily admit water and immerse for ten minutes in hot water at 133° F.; then cool quickly by immersing in cold water or by stirring thoroughly while drying.

1 Ohio Bul. 97, p. 42.
2 Ohio Bul. 42, p. 93.
3 Ohio Bul. 97, p. 60.

(2) **Blue stone** or copper sulphate: Immerse for ten minutes in a solution of copper sulphate at the rate of one pound to five gallons of water. Allow to stand for ten minutes in bag or basket to drain; then spread and dry. Or the seed may be sprinkled at the rate of one gallon of the solution to four bushels of the grain, sprinkling and stirring until thoroughly wet. At the end of an hour dry.

(3) Formalin: Treat seed by sprinkling or immersion for thirty minutes with a solution of one pound of formalin (forty per cent solution of formaldehyde) to fifty gallons of water.

In all treatments it is desirable first to stir seed into a tub of cold water and skim off the smut balls which rise to the surface. After treatment, the drying may be hastened by using slaked lime, but the lime is not essential.



Stinking smut. Single grain much enlarged on the right. (After Kellerman.)

**150. Insect Enemies of Growing Wheat.**—More than one hundred species of insects are known to feed upon the growing wheat plant, but very few are sufficiently injurious to be of economic importance. These few, however, do enormous damage.

The chinch bug has been estimated to cause a loss of over a hundred million dollars to wheat alone in the United States in a single year.[1]

The five most important insect enemies of wheat are as follows:

(1) The chinch bug (*Blissus leucopterus* Say.)
(2) The Hessian fly (*Cecidomyia destructor* Say.)
(3) The wheat bulb-worm (*Meromyza americana* Fitch.)
(4) The wheat midge (*Diplosis tritici* Kirby.)
(5) The wheat plant-louse (*Nectarophora cerealis* Kalt.)

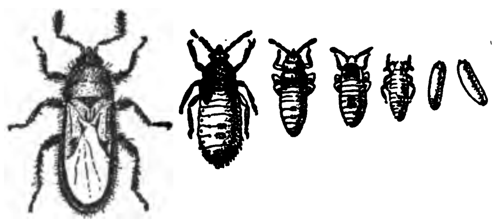
Of the above, the chinch bug and the Hessian fly are by far the most destructive, although the others frequently do considerable damage. Among the wheat insects of secondary importance

[1] C. L. Marlatt: The Principal Insect Enemies of Growing Wheat. U. S. Dept. of Agr., Farmers' Bul. 132, p. 6.

are the wheat straw worms, army worms, wheat sawflies. In the past, grasshoppers, especially the migratory species, have done enormous damage to wheat, but at present this class of insects usually do their greatest injury to meadows and pastures.

There are two general causes for the great damage done to wheat and other grain crops by insects. The long hot summers and the present practice of growing somewhat continuously large areas of wheat on the same land produce favorable conditions for their rapid multiplication. The rotation of crops and a more thorough and more intensive system of agriculture will tend to hold these insects in check.

151. THE CHINCH BUG.—The appearance of the six different stages from the egg to the adult chinch bug is shown in this paragraph. The newly hatched larva is of a pale reddish color with a yellow band across the first two abdominal segments. As the insect changes from one stage to another it changes somewhat in appearance by becoming increasingly darker in color and finally in the adult form by the white wings. So that while in the first larval stage the color was principally red and yellow, in the adult form it is black and white. There is also an adult form with short wings.



The chinch bug: Adult on the left; eggs upon the right; four larval stages between. (Adapted from Riley and Webster.)

The chinch bug passes the winter in the adult form under any object which may offer protection from wet and cold. The grass stools of pastures and meadows, stalks of maize, straw, rubbish in fence and hedgerows furnish them a winter home. The eggs for the spring brood are deposited on the plants beneath the soil not far from May 1st. These eggs reach the adult stage during July; while the second brood reaches its maximum damage in August and its adult stage in September and October. It is the first brood that does the most damage to the wheat, rye or barley, and less frequently to oats, during the last few weeks of the growth of the crop. In the early part of July this brood migrates to maize fields, thereby injuring this crop also.

Preventive measures aside from those already mentioned (150) are the cleaning up or burning of all rubbish or vegetation in fields and fence rows under which the chinch bugs may hibernate. There is no remedy for them while in the wheat

crop, but they may be trapped while migrating to maize fields by means of barriers of various sorts. Millet or Hungarian grass is probably the most effective. After the chinch bugs have congregated in the millet, they should be plowed under deeply,—preferably after spraying with pure kerosene oil. Usually, however, the chinch bug has migrated to the maize fields before protective measures have been inaugurated. The best remedy then is to spray with pure kerosene in the early morning when the chinch bugs will be congregated at the base of the maize plants. The kerosene will do some injury to the maize but not nearly so much as the chinch bugs.

The chinch bug is attacked by two parasitic fungi which tend to hold it in check. A number of experiment stations have propagated and distributed these fungi to farmers for the purpose of spreading them among healthy insects. It has been found, however, that this method is practically effective only during the moist cool weather when the insects are destroyed without the introduction of the disease germs. While the insects are young, even after they have wings, they are migratory in habit, but when the time for the union of sexes comes they take to wing and are no longer noticed by the casual observer. It happens that this occurs from one to three weeks after they migrate to maize fields. Frequently remedies have been reported effective, when in fact the disappearance of the chinch bugs was due to their midsummer flight.

152. THE HESSIAN FLY.—The Hessian fly is a small, two-winged, dusky-colored insect, about one-eighth of an inch long. It is distinctly a wheat pest, but it will also feed upon barley and rye.[1] On account of its small size, the adult insect is seldom observed, and less seldom identified. Crane flies, much larger insects, often swarm about wheat fields and may be mistaken for the Hessian fly.

Hessian fly: A, adult, about three times natural size; B, flaxseed, slightly enlarged; C, larvae, slightly enlarged. (After Washburn.)

The Hessian fly is usually two-brooded, although it may be one-brooded in the northern spring wheat districts, or in the more southerly section of the United States may be three-brooded, the third brood living upon voluntary wheat in the summer months. When two-brooded, the fall brood reaches the adult stage during the latter part of August, during September and the first days of October, depending upon latitude and other seasonal conditions. The adults probably disappear with the first sharp frost. At any rate, the condition which is most favorable to the

[1] Cornell Bul. 194, p. 255.

insect is mild weather for four to six weeks after the wheat is planted. The spring brood reaches the adult stage during the latter part of April, during May and the first part of June.

The adult lays an oval-shaped egg, reddish in color, one-fiftieth of an inch long, on the inner side of the leaf blade. The egg hatches in a few days into a pinkish larva, soon changing to greenish, which finds its way down to the base of the leaf sheath. As the eggs in the fall are usually laid upon the youngest plants, the larvae are to be found somewhat under the ground, where they kill the diminutive culm. In this case the plant will be killed unless it has tillered, and some of the tillered culms escape. In the spring the eggs are laid on leaves somewhat higher up and the larvae will be found at the base of the first two or three leaves above the ground, where the injury causes many of the culms to fall before the grain is ripe. The puparium of the insect resembles in form and color a flaxseed. The pupal stage is therefore called the "flaxseed stage." When two-brooded, this insect passes the winter and the summer in the flaxseed stage.

Preventive measures are (1) late sowing, preferably delayed until after sharp frosts; (2) rotation of crops; (3) burning stubble; (4) sowing strips of wheat early as baits to be plowed under as soon as eggs have been laid. Of these the first two are to be especially recommended. The Hessian fly has many parasitic insects, otherwise it would probably make the raising of wheat impossible. Burning the stubble will destroy the parasites as well as the Hessian fly, which may not always be advisable. The destruction of organic matter also usually will not be desirable. In order to get the best results from late sowing it is advisable for farmers to act together, else the spring brood from the early sown wheat may attack the field which has escaped the fall brood.

There are no Hessian fly proof varieties of wheat, although those varieties which tiller most freely and have the stiffest and hardest culms will doubtless resist their attacks the best.

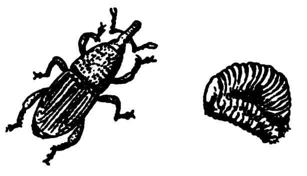
153. THE WHEAT BULB-WORM.—The wheat bulb-worm is a two-winged fly with essentially the same habits as the Hessian fly, except that it lives upon oats as well as several grasses, including timothy. The injury from the fall brood is almost identical with that of the Hessian fly; while the spring brood lays its eggs usually upon the upper leaf, thus causing the culm to wither and die above the upper node. While the Hessian fly therefore usually remains in the stubble after harvest, the wheat bulb-worm is carried from the field with the straw. The damage done by this insect is much less than that of the Hessian fly, for which it is doubtless frequently mistaken.

154. THE WHEAT MIDGE.—The wheat midge is also a two-winged insect. About the time the wheat is in the flower, the adult lays its eggs singly or in clusters to the number of ten upon the glumes of the wheat spike. The larvae suck the milky juice from the young grains, causing them to shrivel. They impart their orange-yellow color to the blighted spike. The insect is probably third in the injury to the wheat plant, but unlike the chinch bug and the Hessian fly, it thrives best in moist weather. The larvae enter the ground after about three weeks and pass the winter in the pupal stage. Many, however, are still in the

spikes when harvested, and are believed to survive in the straw for months without food or moisture.

Preventive measures are (1) the burning of chaff and screenings as soon as the wheat is threshed, and (2) deep plowing of stubble field to bury the larvae and pupae.

155. THE WHEAT PLANT-LOUSE.—This insect appears on winter wheat in September, going through several generations in the early fall but doing little damage. If the spring is cool and moist, its natural enemies may fail to hold it in check and it may then cause considerable damage. Extensive damage has occurred only at rare intervals, as in 1861 and 1899.[1] No effective remedy has yet been suggested.



Beetle and larva of the granary weevil. (After Chittenden.)

156. INSECTS INJURIOUS TO STORED GRAIN.—While upwards of forty different species of insects occur in granaries, the following four species are the most injurious:[2]

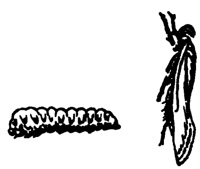
(1) The granary weevil (*Calandra granaria* L.)

(2) The rice weevil (*Calandra oryza* L.)

(3) The Angoumois grain moth (*Sitotroga cerealella* Oliv.)

(4) The wolf moth (*Linea granella* L.)

The first two are beetles and the last two moths. The larvae of the first three live within the grains, as do the adults of both weevils. This adds very much to their injurious effects, to the ease with which they may be distributed, and the difficulty of eradication. All breed more rapidly in warm than in cold weather and consequently do their greatest damage in the southern sections of the country, where they cause enormous losses.



Adult and larva of the Angoumois grain moth. (After Chittenden.)

The simplest and best remedy is the use of bisulphide of carbon at the rate of one pound to one ton of grain or in empty rooms for every 1,000 cubic feet.

There are a number of insects injurious to flour. The Mediterranean flour moth (*Ephestia kuehniella* Zell.) has recently become a most serious pest, requiring the adoption of extensive precautions in flouring mills to guard against its ravages.

## II. HARVESTING AND PRESERVATION.

157. **Date of Harvesting.**—The wheat harvest of the United States begins in Texas in May and ends in the Dakotas in August. In California the harvest begins about June 1st and

[1] U. S. Dept. of Agr., Farmers' Bul. 132, p. 24.

[2] For a description and life history of these insects see U. S. Dept. of Agr., Farmers' Bul. 45.

lasts till August 1st. Everywhere east of the Great Plains. wheat is cut as soon as or a little before it is ripe, and the harvest extends on any one farm not longer than two or three weeks, the wheat being cut as fast as it is ready. In California, where there is no danger from rain, the harvest extends for many weeks after the wheat is ripe, some of it standing even ten weeks after it is ripe enough to cut. The only damage done to the standing wheat in this section is by occasional sand storms. The type of wheat usually raised is the club or square head, whose short culms prevent it from lodging.

The calendar of the wheat harvest of the world is given by Edgar as follows:

"In January, Australasia, Chili and Argentina; in February and March, East India, Upper Egypt; in April, Lower Egypt, Asia Minor and Mexico; in May, Algeria, Central Asia, China, Japan and Texas; in June, Turkey, Spain, southern France, California, Tennessee, Virginia, Kentucky, Kansas, Utah and Missouri: in July, Roumania, Austria-Hungary, southern Russia, Germany, Switzerland, France, southern England, Oregon, Nebraska, southern Minnesota, Wisconsin, Colorado, Washington, Iowa, Illinois, Indiana, Michigan, Ohio, New York, New England, eastern Canada; in August, Holland, Belgium, Great Britain, Denmark, Poland, western Canada, the Dakotas; in September and October, Scotland, Sweden, Norway, North Russia; in November, Peru and South Africa; in December, Burmah and Argentina."[1]

158. **Stage of Maturity on Yield.**—The usual practice in the eastern half of the United States is to cut when the straw begins to turn yellow and the grains are in the dough, soft enough to be easily indented with the thumb nail and hard enough not to be easily crushed between the fingers. Investigations indicate that there is a continuous increase of the plant during its growth until the plant is entirely ripe. There is a continuous increase in the weight of the grain from the time it is formed until it is hard and dry. The increase in weight of grain is most rapid up to the time when the grain can be crushed between the thumb and finger. The increase seems to be decided and of economic importance up to the time when the grains indent but

[1] Wm. C. Edgar: Story of a Grain of Wheat (1903), p. 191.

do not crush under the pressure of the thumb nail. After that time the increase is slight. The indications are that if allowed to stand beyond the period of full maturation, a slight decrease in the actual substance of the grain may take place. This is explained by Deherain on the ground that the seed continues to respire, thus giving off carbon dioxide.

159. **Influence of Ripening Upon Composition.**—In general, there is a decrease in the percentage of ash, nitrogen and fiber as the grain ripens, due to the increase in carbohydrates other than fiber. This is due to the endosperm developing later in the growth of the wheat. The germ develops first, and later, when the endosperm develops, the percentage of ash and nitrogen becomes less, although the actual amount may remain the same, or, as is probably the case, may increase. The changes in composition after the grain has reached the dough stage appear to be very slight.[1]

While the stage of maturity of grain through the ordinary range of wheat harvest does not affect materially the quality (composition) of the grain, climatic conditions which affect the full maturity of the grain may materially modify the quality. The higher percentage of nitrogen in the spring wheat is probably due, in part at least, to a lack of full maturation. (74) The per cent of nitrogen decreases somewhat in the straw up to the dough stage. The per cent of crude fiber increases in the straw throughout the ripening period, while there are corresponding decreases in the other carbohydrates.

160. **Influence of Shocking.**—There is always danger of overripe grain shelling out in the harvesting, and there is also danger of lodging. It is not good farm practice, therefore, to delay harvesting until wheat is entirely ripe. Investigations have proved beyond question that at the early stages of seed formation a considerable transfer of material from the straw to

1 Mich. Bul. 101, p. 8.

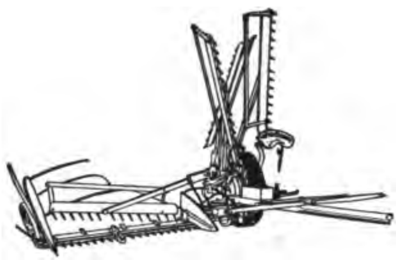
the grain may occur after cutting, when the wheat is placed in a condition similar to the shocking and capping of bound sheaves.[1] Prompt shocking and capping, therefore, facilitate the completion of the ripening process. Where it is necessary to cut the wheat quite green, it is important that the sheaves should not be left long on the ground exposed to the hot sun

161. **Method of Shocking.**—The sheaves may be put in long shocks by placing pairs of sheaves in a row, about a dozen bundles to the shock, or preferably in round shocks with caps, twelve to sixteen bundles to the shock, depending upon the size of the bundles, the stage of maturity and the amount of green weeds. In building a shock of twelve bundles, place three pairs in a row, then place two bundles on each side, making ten bundles. Now lay one bundle on the top, then take another bundle, break both ends of the bundle at the band, spreading the ends fan-shape, and lay this crosswise of first bundle. In some cases only one bundle is used, treating it as just indicated, and in other instances the caps are entirely omitted. Usually, however, capping with two bundles is to be preferred. In building a shock of sixteen bundles, place four pairs in a row, then three bundles on each side, and cap with two bundles. Both for efficiency and economy of time, two bundles should be handled at once, and care should be taken to place the bundles firmly on the ground. There is a knack in shocking that may be easily learned by practice, which adds greatly to the ability of the shocks to withstand wind storms

162. **Methods of Harvesting**—There are four types of power machines for harvesting wheat and other stored grain in the United States at the present time. They are: (1) the self-rake reaper; (2) the self-binding harvester; (3) the header; and (4) combined harvester and thresher. The hand cradle is still manufactured and used for harvesting small areas.

1 Ill. Buls. 11 (1890), p. 349, and 22 (1892), p. 119. Mich. Bul. 125 (1895), p. 34.

163. **Self-Rake Reaper.**—All harvesting machines have certain features in common. These are the serrated sickle vibrating through stationary guards, a platform to receive the cut grain, some provision to bring the grain regularly against the sickle and deposit it on the platform, a divider to separate the swath to be cut from the remainder of the standing grain, and some means by which the operator can quickly raise or lower the cutter bar while the machine is in motion.



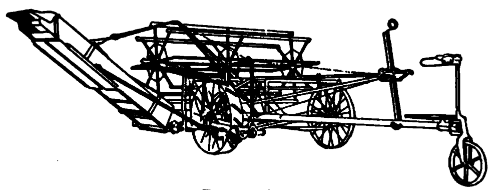
The self-rake reaper.

In the self-rake reaper the platform has the form of a quarter of a circle, and upon it operate automatically rakes which serve the double purpose of bringing the grain onto the platform and removing it from the platform far enough to one side so that the reaper can again pass around the field without running over the cut grain. The size of the bundle is determined by regulating the number of rakes which remove the grain. Because of the necessity of binding the grain by hand, they are used only where small quantities are to be harvested. The reaper cuts a swath of five feet and is drawn by two horses. An ordinary day's work is from six to eight acres.

The self-binding harvester.

164. **The Self-Binding Harvester.**—By far the larger area of small grain is now harvested by this machine, generally called the "binder."

They are manufactured in a number of styles, but in their essential features they are nearly all practically identical. It differs from the reaper in having a reel to bring the grain against the cutter bar and deposit it on the platform. This reel is attachable at the will of the operator while the machine is in motion. The cut grain is conveyed on an endless canvas to an elevator consisting of two endless canvases which deposit the grain on the opposite side of the drive wheel, where it is packed into a trim bundle and automatically bound with twine. The binding device operates as often as the pressure of the increasing bundle trips it. The size of the bundle is therefore determined by regulating the pressure required to trip the binder. Binders are made which cut different widths, the standard width being six feet. Three horses are used with the six-foot cut, and an ordinary day's work is from ten to twenty acres, depending upon many factors, the most important of which are the yield and the condition of the straw.

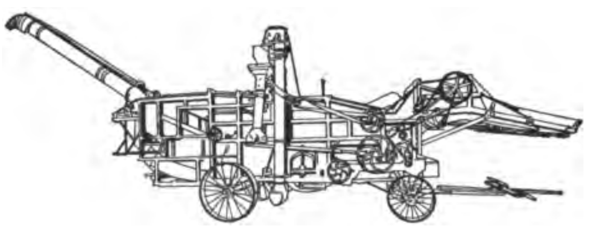

The header.

**165. The Header.**—The header and the combined harvester can be used only where the climate is such as to permit harvesting the wheat after it is fully ripe and thoroughly dry, and hence are in use only in the western half of the United States. Instead of cutting the wheat near the ground, they merely head it, leaving the bulk of the straw standing in the field. The header conveys the headed grain to the side of the machine and elevates it so that it is deposited in a wagon driven alongside to receive it. The grain is either immediately carried to a threshing machine or first put in stacks and subsequently threshed.

The header cuts a swath twelve and twenty feet wide, and is usually pushed by four horses. An ordinary day's work is fifteen to thirty acres.

**166. The Combined Harvester and Thresher.**—This machine is a combined header and threshing machine. The standard machine of this type cuts a swath eighteen feet wide, the cutter bar being attached directly at the side and forward end of the thresher. The headed grain is conveyed to the thresher, which is made to operate by being pulled over the ground by twenty-eight horses or mules. The animals are hitched in three sets of six, then two sets of four. In front of these are two, and to this pair alone are lines attached. It requires four men to operate this machine: one to drive, one to tilt cutter bar, one to sew filled sacks and dump upon ground from time to time as they accumulate in groups of six or eight, and one to have general charge of the machine. Five to seven hundred bushels of wheat may be harvested, threshed and sacked with one of these machines in a day. There are

The combined harvester and thresher, propelled by traction engine, with an extension to platform and sickle bar, making it possible to cut a swath forty feet wide.



Separator with grain feeder, wind stacker and grain weigher.

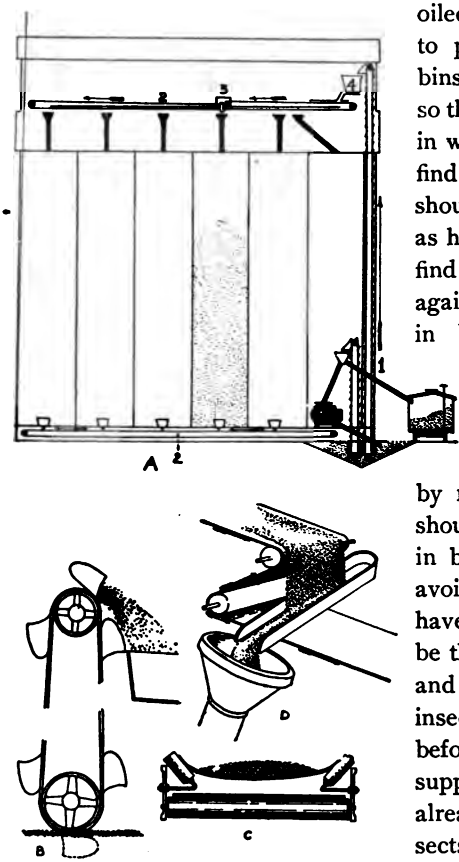
still larger machines, cutting a swath twenty-five or more feet in width and operated by steam power, and doing a correspondingly larger amount of work.

**167. Threshing.**—In some sections of the country the wheat is mostly threshed directly from the shock, while in other sections it is first stacked or stored in the barn and after the grain has had time to go through the sweat, it is threshed. There is little more danger of the threshed grain heating in the bin if threshed directly from the shock, but where care is taken to have the grain thoroughly dry, heating will not occur. Under such circumstances, there is no material difference in the quality of the grain or of the resulting flour. Probably much of the larger part of the wheat harvested in the United States is threshed directly from the shock. Rainy weather may cause damage, which can be guarded against in some measure by storing in barn or by stacking, but ordinarily it is largely a matter of economy and convenience. The sprouting of wheat not only greatly decreases the quality of the grain, but it has been shown that sprouting wheat for six days or until grains are beginning to burst their first leaf, may cause a loss of twelve per cent in weight.[1] A few farmers own their own threshing machines, and very rarely a machine is permanently located in the barn in accordance with the English custom. Ordinarily, however, the threshing is done by the itinerant steam threshing outfit which does the work for a stated price per bushel. Usually 500 to 1,000 bushels are threshed per day.

**168. Storing.**—The principal things to be considered in the storing of wheat are the ease of handling, freedom from dampness, insects and vermin. Wheat is not injured by cold, and insects injurious to wheat do not thrive at cold temperatures, consequently the more exposed the granary the better. The larger the bulk of grain and less the exposure of the surface, the less will be the injury from insects. The surface of the rooms and

1 Ark. Bul. 42 (1896), p. 72.

bins should be constructed so as to prevent lodgment of insects, as far as possible, by having smooth surfaces which are preferably oiled or painted. In order to prevent rats and mice, bins should never be built so that there are air spaces in which these vermin can find hiding places, nor should other objects, such as hay, in which they can find lodgment, be placed against the bins. Wheat in bins made of single thickness of boards and fully exposed on all sides will never be seriously injured by rats or mice. Wheat should never be stored in bags where it can be avoided. Granaries that have been in use should be thoroughly cleaned out and treated to destroy insects if necessary (156) before putting in fresh supplies of grain. Grain already affected with insects should be put in quarantine bin and treated before being placed into the granary. Wherever the granary and rice weevil and the Angoumois grain




A, diagram of an elevator: 1, endless band and elevator buckets for raising grain; 2, grain belt for moving grain horizontally; 3, zigzag for delivering grain from belt to hopper; 4, weighing bin. B, detail of endless band and elevator buckets. C, detail of grain belt. D, detail of zigzag. (After Cobb.)

moth are likely to be serious pests, windows should be covered with screens, doors made tight, and every precaution taken to keep them from gaining entrance to the granary.

Aside from the losses occasioned by insects and vermin, the loss of weight through storage is a negligible quantity.

169. **Elevators.**—The elevator is an American institution which has immensely facilitated the handling of wheat and other grains, due to the fact that "threshed grain can, in large measure, be handled like water." Wheat may be run directly from the threshing machine into tight wagon boxes holding fifty to 100 bushels and hauled directly to the elevator, where it is automatically dumped and elevated by power machinery, so that a pound of grain need not be lifted by hand after it starts into the threshing machine. Or it may be temporarily stored in two-bushel bags and subsequently drawn to the elevator.


A country elevator.

The elevator company will receive, insure and store wheat for fifteen days at a fixed charge, and store indefinitely thereafter for a fixed charge, depending upon the length of storage. It will also clean the wheat if desired. The owner receives a certificate of the amount of wheat stored, which he can sell whenever he desires to do so.


Terminal elevator.

Country elevators are usually built of wood and have a capacity of 20,000 to 40,000 bushels; while elevators at terminal points have been built which hold 3,000,000 bushels and are now being made of steel, concrete, or tile, thus saving largely in insurance. On the Pacific Coast, the wheat is still handled in sacks as in other countries.

# VII.

## WHEAT.

### I. USES AND PREPARATION FOR USE.

170. **Uses.**—The use of wheat as a human food is prehistoric, but by no means universal, although much more so than formerly. It is only since the application of machinery to wheat harvesting and the simultaneous development of new wheat areas, that the coarser grains have come to take a more secondary place in our dietary. The ancient Egyptians lived upon barley, sorghum seed, lupines and horse beans. Esau's mess of pottage was hulled lupines. Our New England forefathers ate "rye and Indian" (a mixture of rye and maize meal) and buckwheat principally. Wheat is almost exclusively used for the production of flour from which various forms of food are made, while its by-products serve as food for domestic animals. The value of wheat as human food does not lie so much in its superiority in sustaining life as it does in its greater palatability and the attractiveness and great variety of forms which can be made therefrom.

171. **Food for Domestic Animals.**—All classes of domestic animals are fond of wheat, whether fed whole or ground, wet or dry. Feeding experiments clearly indicate that the food value of wheat is slightly, if any, greater than maize, pound for pound, when fed to domestic animals. When the price permits its use under these conditions, it is a healthful and desirable food, but the best results are obtained when it does not form more than half the grain ration. When fed whole, large quantities of the grains escape mastication, but grinding has been found to increase slightly its food value. The Minnesota Station found

that when fed to pigs, ground wheat was about ten per cent more digestible than whole wheat.[1] The Ohio State University reports one experiment in which 399 pounds of both ground and moistened wheat produced 100 pounds of increase in pork as compared with 453 pounds of whole dry wheat. The South Dakota Station found 491 pounds of whole dry wheat and 481 pounds of ground dry wheat produced 100 pounds of increase.

172. **Source, Amount and Quality of Flour.**—In the process of milling the aim is to reduce the endosperm to a very fine powder with as little admixture of other portions of the grain as possible. The following table gives the analysis of cleaned wheat and of three grades of flour produced therefrom by the roller process of milling.[2]

| | Wheat | (1) Patent flour | (2) Bakers' flour | (3) Low grade flour |
|---|---|---|---|---|
| Water | 9.07 | 11.48 | 12.18 | 12.01 |
| Ash | 1.79 | .39 | .62 | 1.99 |
| Protein (N x 6.25) | 14.35 | 12.95 | 14.88 | 17.95 |
| Crude fiber | 1.68 | .18 | .33 | .93 |
| Nitrogen-free extract | 70.37 | 73.55 | 69.99 | 63.26 |
| Fat | 2.74 | 1.45 | 2.00 | 3.86 |
| Phosphoric acid | .82 | .18 | .31 | 1.16 |

(1) Patent flour: A clear white grain.

(2) Bakers' flour: Slightly yellow in color. The grain lacks distinctness, making the flour lumpy.

(3) Low grade flour: The grain is soft and the flour dark and lumpy. Particles of embryo and bran are prominent.

The low grade flour was somewhat higher in protein, considerably higher in crude fiber and much higher in phosphoric acid than the patent flour. The patent flour, which presumably formed the bulk of the product, was lower in protein and phosphoric acid than the grain. All grades of flour were lower in

1 Minn. Bul. 36, p. 147.

2 U. S. Dept. of Agr., Div. of Chem. Bul. 4 (1884), pp. 38-39.

crude fiber than the grain. The highest grades consist of approximately pure endosperm, but since in producing these highest grades it is necessary to reject practically all of those portions of the endosperm that remain attached to the embryo and to the aleurone layer, it is customary in the roller process of milling to make several grades of flour with varying admixtures of portions foreign to the endosperm, in order to increase the total percentage of the flour. The superiority of the modern methods of milling lies largely in the exactness with which the various products of the wheat grain can be sorted. The almost complete elimination of crude fiber in the patent flour is probably one of the most important factors in affecting its commercial and breadmaking value. Another rather important factor is the fineness of the particles of flour. While flour seems like an impalpable powder, there is in reality considerable variation in the size of the particles, as may be readily determined by passing flour through sieves of proper dimensions. Microscopic examination will show that some particles are spherical, while others are angular. Flour from hard wheat is generally larger and more angular than that from soft wheat. The character of the milling has, of course, the greatest effect upon the granulation of the flour. The most desirable condition for breadmaking probably exists when the flour is of medium granulation, with a mixture of medium and smaller sized particles, as the capacity of the flour to absorb water is thus increased.[1]

The quantity and quality of the flour therefore depend upon the character of the wheat grain both physically and chemically, upon its condition at the time of milling, upon the mill and upon the skill of the miller. Usually seventy to seventy-two per cent of the grain is made into flour, although variations ranging from sixty-five to eighty per cent have been reported for different varieties of wheat milled by the roller process.[2] Where

1 The Northwestern Miller, Christmas, 1900, p. 20.

2 U. S Dept. of Agr., Div. of Chem. Bul. 4 (1884), p. 60.

millers do custom milling for an eighth toll, it is customary to give thirty-six to thirty-seven pounds of flour and twelve to fourteen pounds of mill feed for each bushel. While wide variations may occur on account of differences in the process of milling and mixing, ordinarily about one-half the by-product is bran, and the other half shorts and middlings.

The larger the endosperm and the smaller the embryo and aleurone layer, the larger the percentage of flour obtained. The evidence seems conclusive that the embryo and aleurone layer are considerably higher in ash, and especially in phosphoric acid, nitrogenous compounds and fat, than the endosperm, and that the composition of wheat may vary on account of the proportion of these to endosperm without any variation in the composition of the endosperm. There is, therefore, no necessary relation between the composition of the wheat grain and the composition of the flour therefrom. In general, however, grains with high percentage of nitrogenous compounds produce flour with high percentage of these compounds and with high gluten content. (69)

173. **Grades of Flour.**—The expert miller determines the quality of the flour largely by feel and color. Great expertness is acquired in judging of the granulations by the feel, which depends both on the size of the flour particles and their form. The quality of the flour also depends upon the per cent and quality of the gluten. (70) The quality of the gluten may be determined by the "baker's sponge test" by which the volume of dough per unit of gluten as well as the time required to obtain the maximum rise is determined. (204)

Many trade names are given to different grades of flour by manufacturers. Dealers have sought to obtain uniformity of grading by a system of inspection similar to that employed for whole wheat and other grains. As a guide for the inspector, a series of standards is prepared and renewed from time to time as required. The classification differs in different cities. In

St. Louis the grades are Patent, Extra Fancy, Fancy, Choice and Family, in which the first named indicates the whitest and highest quality, and the last the darkest and lowest grade.[1]

174. **Graham and Entire Wheat Flour.**—Graham flour is unbolted wheat meal, while whole wheat or entire wheat flour is wheat meal from which the coarsest of the bran has been removed. It contains, therefore, the embryo and perhaps some portion of the aleurone layer.

The following table gives the composition of a hard Scotch fife wheat, and of graham flour, entire wheat flour and of straight grade patent white flour made therefrom:[2]

| | Wheat | Graham flour | Entire wheat flour | Straight grade patent flour |
|---|---|---|---|---|
| Water | 8.50 | 8.61 | 10.81 | 10.54 |
| Ash | 1.80 | 1.72 | 1.02 | .50 |
| Protein (N x 5.7) | 12.65 | 12.65 | 12.26 | 11.99 |
| Carbohydrates | 74.69 | 74.58 | 73.67 | 75.36 |
| Fat | 2.36 | 2.44 | 2.24 | 1.61 |

When made into bread it was found that the white flour made the lightest bread (the largest loaf) and that the graham flour made the smallest loaf. Expressing the digestibility of the bread when fed to men in terms of available energy, it was found that 90.1 per cent of the white bread, 85.5 per cent of the entire wheat bread and 80.7 per cent of the graham bread was digested. The greater digestibility of the white flour was, in part, attributed to its greater fineness. The result of this and other experiments indicates that while bread from graham and entire wheat flour is a perfectly healthful and often desirable article of diet, bread from white flour produces the largest amount of

1 Ark. Bul. 42, p. 66.

2 Minn. Bul. 74, p. 157.

energy per unit of flour and is probably to be preferred as the main diet for the average person. The digestibility of bread from different grades of patent flour was quite similar.

175. **Amount of Bread from Flour.**—The value of flour depends upon the amount and quality of bread produced. (172) The amount of bread does not, however, depend upon the flour alone but also upon the conditions of baking, chief of which are the percentage of water used in the dough, the size of the loaves, the temperature of the ovens and the length of time of baking. Richardson reports that by differences in these factors the amount of bread may be varied as much as fifteen pounds per 100 pounds of flour. For different flours handled as nearly alike as may be, he obtained variations ranging from 129 pounds to 140 pounds of cold bread for each 100 pounds of flour, and he concludes that the yield of bread is dependent on physical conditions of breadmaking and not to a large extent upon the chemical composition of the wheat (flour).[1] It was a fact, however, that the flour with the least per cent of nitrogen produced the smallest per cent of bread and the flour with the largest per cent of nitrogen produced the largest per cent of bread. As the percentage of flour in wheat is about seventy-two, each pound of wheat produces about a pound of bread.

176. **Milling Machinery.**—There are three types of machinery for producing flour which may be represented as follows:

1. The mortar and pestle, which is the primitive method, in which the force employed is principally that of impact.

2. Burr stones, which was the universal method of milling wheat in the United States until 1878, in which the wheat is cut and crushed.

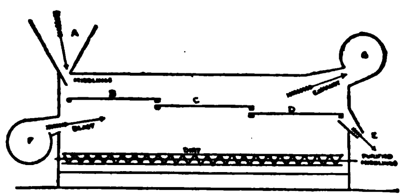
3. The roller process, which has made large mills possible, in which the wheat, and subsequently its several parts, pass through a series of graduated hardened steel rollers and in which

[1] U. S. Dept. of Agr., Bu. of Chem. Bul. 4, pp. 60-62.

the material is mashed, rather than torn as in the burr stones. There were in the United States in 1900 about two and one-half as many pairs of rolls as runs of stone.

The separation of the different portions of the grain is accomplished partly by gravity and partly by bolting cloth of different sized meshes. The endosperm breaks up into spherical or cubical particles, while the other portions are more or less flattened, forming comparatively larger dimensions and having a less specific gravity.

177. **The Purifier.**—Formerly, and by what is now known as the old process of milling, wheat was merely ground as finely as possible and then bolted. By the introduction of the middlings purifier two steps have been added to the process, viz., purifying and regrinding. The details of this "new" process are elaborate and complicated but the principles involved are quite simple. The thoroughly cleaned wheat, whether rolls or burrs are used, is first ground, or rather granulated coarsely, resulting in three products: flour of a low grade, middlings and bran. The middlings are now put through the purifier in order to extract dirt, bran and fuzz. They are then ground by a more or less gradual process, depending upon the construction of the mill, and finally bolted. It is from these middlings thus purified that the highest grade (so-called patent) of flour is made.



The middlings purifier, which has greatly influenced the wheat industry.

The introduction of the purifier in 1870 revolutionized the process of milling, and made the use of the hard spring wheats of the Northwest of the highest value, while formerly they were of the least value for the production of high grade flour.

178. **The By-products of Wheat** consist of the outer coats, the aleurone layer, the embryo, and such portions of the endosperm as cannot, by the common process of milling, be removed from the aleurone layer. There are a number of grades of these by-products, depending principally upon the relative proportion of outer coats to endosperm. The common grades are bran, shorts and middlings, while a low grade of flour known as "red dog" or "dark feeding flour" is sometimes sold for feeding purposes. Bran and shorts are essentially the same, except that in the process of milling the outer coats in the latter are more thoroughly pulverized; while the middlings contain a larger portion of the endosperm, and are therefore more starchy and dense than bran or even shorts. In the bran the outer coats are in large flakes, with portions of the aleurone layer and endosperm attached, thus making a light, bulky product. While the embryo itself constitutes a much smaller proportion, in the process of milling about eight per cent of the grain is removed as embryo. (64) Care is taken to remove these embryos, because their introduction into the flour injures its keeping qualities, and its nitrogenous compounds are not suitable for breadmaking purposes.[1] On account of their high nitrogen, phosphorus and fat content, they are a valuable addition to the by-products. They are sometimes found in the bran and sometimes in the middlings. As in the process of milling they are separated from the rest of the products, it is optional with the miller where they are put. The yellowish flattened embryos are readily recognized in the mill products.

179. **Composition of By-products.**—The analyses that have been compiled show very great variations in every constituent in different samples of bran, shorts and middlings.[2] Taking them as a class, the ash has been found to vary from 1.4 to 7.8 per cent; the protein from 10.1 to 20.0 per cent; the crude

[1] The Chemistry of Plant and Animal Life, p. 307.

[2] U. S. Dept. of Agr., Office of Expt. Sta. Bul. 11.

fiber from 1.3 to 15.5 per cent; nitrogen-free extract from 45.5 to 70.9 per cent; and fat from 1.5 to 7.0 per cent.

The following table shows the average composition:

| | Bran | Shorts | Middlings |
|---|---|---|---|
| Number of analyses | 88 | 12 | 32 |
| Water | 11.9 | 11.8 | 12.1 |
| Ash | 5.8 | 4.6 | 3.3 |
| Protein (N x 6.25) | 15.4 | 14.9 | 15.6 |
| Crude fiber | 9.0 | 7.4 | 4.6 |
| Nitrogen-free extract | 53.9 | 56.8 | 60.4 |
| Fat | 4.0 | 4.5 | 4.0 |

High protein content may be accompanied with high content of crude fiber and low content of starch due to exhaustive milling, and equal protein content may result in two samples of bran unequally milled because of differences in the protein content of the wheat used.

The total phosphorus in wheat bran has been found by the New York (Geneva) Station to be 1.22 per cent, as compared with 0.7 per cent in malt sprouts and 0.4 in oats. It is also more soluble, eighty-seven per cent being soluble in water, as compared with eighty-one per cent in malt sprouts and fifty per cent in oats. Practically all of the soluble phosphorus of wheat bran is of an organic nature.[1]

180. **Food Value of By-products.**—Within the memory of many persons now living, the bran spout of grist mills emptied its contents into the river. The by-products of wheat are now among the most highly prized stock foods for all classes of domestic animals. While its value is undoubted, the digestibility of bran is not much greater than that of hay of good quality. The esteem in which it is held sometimes causes it to be an expensive food compared with others that are available.

[1] N. Y. (Geneva) Bul. 250 (1904), p. 169.

Middlings usually sell for about five per cent more and shorts for about five per cent less than bran. So far as the ruminants are concerned, these values are not the result of experimental evidence. For ruminants and horses, the mixing of bran and middlings is probably advisable. Shorts are to be avoided on account of the practice of millers in adding the sweepings and other inferior products.[1] The Maine Station has shown that for swine, middlings are much more desirable than bran, undoubtedly due to the less percentage of crude fiber in the former.[2]

## II. PRODUCTION AND MARKETING.

**181. Wheat Crop of the World.**—The production of wheat in the world has varied during the years 1898 to 1902 inclusive from 2,610 to 3,124 million bushels per annum, the average yearly production being 2,869 million bushels.

The following table gives the average annual production by half decades by continents in million bushels:

| | 1893-1897 inclusive | 1898-1902 inclusive |
|---|---|---|
| Europe | 1,433 | 1,580 |
| North America | 520 | 717 |
| Asia | 409 | 382 |
| South America | 74 | 96 |
| Australasia | 34 | 48 |
| Africa | 45 | 45 |
| Total | 2,515 | 2,868 |

This table shows that, compared with the preceding five years, Australasia has made the largest percentage increase. North America has made the largest actual increase in the production of wheat. The production of wheat in Africa has remained stationary, while in Asia it has fallen off seven per

[1] W. A. Henry: Feeds and Feeding, p. 130.

[2] Me. Rpt. 1889, p. 82.

cent. The increased production in North America has been greater than all the rest of the world combined.

Notwithstanding the great development of wheat production in other sections of the world, Europe still produces more than half the wheat of the world, and notwithstanding the fact that much of Europe has been cultivated for ages, the production of wheat continues to increase in a substantial manner. Russia, France and Austria-Hungary are the largest wheat producing countries of Europe. Second in importance to these are Germany, Spain and Italy. The United States and India are the only other large wheat producing countries. Canada and the Argentine Republic are important on account of having a relatively large surplus for export and on account of the possible future development. The Canadian Northwest is distinguished for its large yield per acre combined with high quality of the grain.

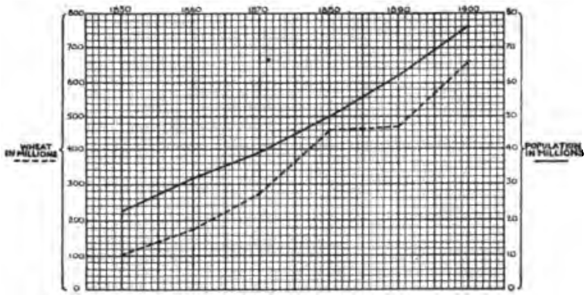
**182. Wheat Crop of the United States.**—The United States raises the most wheat of any nation on the globe. The largest yield ever produced in a single year was 748 million bushels in 1901. The following table presents the essential statistics for the last three decades, based upon the estimates of the United States Department of Agriculture:

| | 1870–1879 | 1880–1889 | 1890–1899 |
|---|---|---|---|
| Area, acres | 25,000,000 | 37,000,000 | 38,000,000 |
| Yield, bushels | 312,000,000 | 450,000,000 | 503,000,000 |
| Value, dollars | 327,000,000 | 372,000,000 | 330,000,000 |
| Price per bushel, dollars [1] | 1.05 | 0.83 | 0.65 |
| Yield per acre, bushels | 12.4 | 12.1 | 13.2 |
| Value per acre, dollars | 13.00 | 10.00 | 8.58 |

These figures show a steady decrease in the value of the crop per acre through a decrease in price per bushel. The yield per acre has increased somewhat, due in part, no doubt, to the opening of new sections to the production of wheat which give high yields per acre. The census for 1900 shows that practically all

[1] Farm price December 1st.

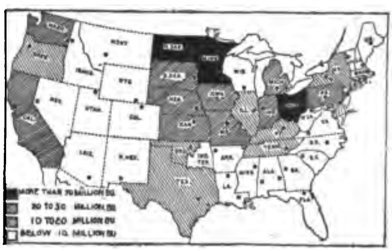
of the territory reporting over twenty-one bushels per acre was west of Denver. The greater part of that in which the yield is from fourteen to twenty-one bushels per acre is found north of the Potomac and east of the Missouri.



The relative increase in population and in production of wheat in the United States according to reports of the census.

In 1899, thirty-five farms out of every hundred in the United States produced wheat. A little more than two million farms are reported by the census to have produced 659 million bushels of wheat from an area of fifty-three million acres.

**183. Progress of Wheat Production.**—Owing to the possession of large areas of fresh lands, easily brought into cultivation, to the reduced cost of production and handling through the introduction of labor-saving machinery and the extension of railway construction, the progress of wheat production has been rapid. In fifty years the production of wheat has increased six and one-half times.



Map showing the production of wheat in the United States in 1900.

This diagram indicates that during the past decade the production of wheat has increased faster than population, while average annual yields by decades based upon the estimates of the United States Department of Agriculture indicate that the production of wheat has not increased as rapidly as population. (182)

**184. Center of Wheat Production.**—While wheat is grown in every State in the Union, the greater part is raised in the Mississippi Valley. Ten States produced sixty-five per cent, twenty States produced ninety per cent of all the wheat grown in the United States in 1900.

The center of wheat production in 1900 was about seventy miles west of Des Moines, Iowa (N. Lat. 41° 39′ 19″ and W. Long. 94° 59′ 23″). In fifty years this center has moved north about ninety-nine miles and west about 680 miles.

**185. Winter Wheat and Spring Wheat.**—In 1902 about three-fifths of the wheat of the United States was sown in the fall. The yield for winter wheat was 14.4 and for spring wheat 14.7 bushels per acre.

Wisconsin, Iowa, Kansas, Nebraska, Idaho, Washington and Oregon produce both winter and spring wheat. Minnesota, North Dakota, South Dakota, Colorado, Utah, Montana, New Mexico, Wyoming, Nevada, Arizona, Maine and Vermont raise spring wheat, while the rest of the States raise winter wheat.

Map showing ten States each grinding more than twenty million bushels of wheat in 1900.

**186. Production of Flour.**—There were about 490 million bushels of wheat made into flour in the United States in 1900. A little more than two-thirds of it was

ground in ten States, Minnesota alone grinding 103 million bushels.

187. **Consumption of Wheat per Capita.**—The census[1] estimates the domestic consumption of flour to be equal to 5.31 bushels of wheat per capita in 1900, as compared with 5.29 bushels in 1890. As it takes 4.77 bushels of wheat to make a barrel of flour, this is 1.1 barrels of flour per inhabitant. About 1.4 bushels per acre, or about eleven per cent of the normal crop, is estimated to be required for seed. This makes the total requirement aside from its use as food for domestic animals and such secondary uses as breakfast foods, 6.29 bushels per inhabitant, or about 475 million bushels for the United States in 1900.

A wheat field producing forty-eight bushels of wheat per acre on one of the farms of Cornell University, Ithaca, N. Y.

According to the Bureau of Statistics of the United States Treasury Department[2] the total amount of wheat used for all purposes for the five years ending 1902 was 390 million bushels, as compared with 300 million during the preceding five years.

For the five years ending 1902, the production of wheat in Europe has been 4.1 bushels per capita. The net import of wheat has been something less than one bushel per capita.

1 Twelfth Census of the United States, 1900. Vol. VI. Agr. Part II, p. 32.

2 U. S. Treas. Dept., Bu. of Stat. Statistical Abst., 1902, p. 345.

This does not, however, represent Europe's total bread requirement, as large quantities of rye bread are used by the inhabitants of several European countries.

188. **Yield per Acre.**—There is a marked variation in yield per acre of wheat in different countries. It will be seen that the two countries which produce the most wheat have the smallest yield per acre.

Average yield of wheat in bushels per acre, 1894-1900:

| | |
|---|---|
| United Kingdom | 31.8 |
| Germany | 26.0 |
| France | 19.4 |
| Hungary | 17.1 |
| Austria | 16.4 |
| United States | 13.4 |
| Russia | 9.0 |

Climate apparently has a greater influence in bringing about these differences in yield than either soil or cultural methods, although the latter are important factors. A moderately cool climate with a liberal supply of moisture prolongs the period during which the grain develops, thus favoring the development of the endosperm and thereby increasing the volume weight and the yield per acre. (74, 112)

189. **Export of Wheat and Flour.**—The world's export of wheat and flour for the half decade 1898-1902 ranged from 347 million (1900) to 444 million (1902) with an average annual exportation of 411 million bushels. During the same period the exportation of wheat and flour from the United States was equivalent to 215 million bushels of wheat per annum, as compared with 155 million bushels the preceding five years, which was thirty-six and thirty-four per cent respectively of the total production. The following table is an estimate of the world's average annual export of wheat and flour for the five years 1898 1902:[1]

[1] U. S. Dept. of Agr. Yearbook, 1902, p. 770.

| | 1898-1902 Bushels |
|---|---|
| North America | 229,990,400 |
| Russia | 82,972,800 |
| Balkan Peninsula | 30,548,800 |
| Argentina and Uruguay | 41,112,000 |
| India | 15,935,200 |
| Australia and New Zealand | 10,199,200 |
| Total | 410,758,400 |

The following table gives the exportation of wheat and flour from the United States by customs districts for the year ending June 30, 1902:[1]

| Wheat | Bushels | Price per bu. | Total value |
|---|---|---|---|
| I—Atlantic ports | 71,589[2] | $0.783 | $56,112[2] |
| II—Gulf ports | 29,458 | 0.735 | 21,670 |
| III—Mexican border ports | 885 | 0.798 | 706 |
| IV—Pacific ports | 42,581 | 0.628 | 26,763 |
| V—Northern border and Lake ports | 10,341 | 0.736 | 7,621 |

| Flour | Barrels | Price per barrel | Total value |
|---|---|---|---|
| I—Atlantic ports | 13,086[2] | $3.85 | $50,435[2] |
| II—Gulf ports | 947 | 3.75 | 3,553 |
| III—Mexican border ports | 44 | 4.01 | 178 |
| IV—Pacific ports | 3,059 | 2.97 | 9,112 |
| V—Northern border and Lake ports | 621 | 3.83 | 2,382 |

[2] The figures are stated in thousands.

The average annual export price of wheat from United States, 1898 to 1902, inclusive, was 78 cents per bushel; for flour $3.90 per barrel.

More than ninety-eight per cent of the wheat exported from the United States in 1902 was shipped from twenty ports. For the five years, 1898-1902, seven of these ports sending out

[1] Commerce and Navigation of United States. Treas. An. Rpt. 1902, Vol. I pp. 496-497.

more than ten million bushels annually, held the following rank: New York, New Orleans, Baltimore, Galveston, Boston, San Francisco, Willamette (Ore.). New York was the only port sending out as much as twenty millions annually, and her average annual shipment for the five years given was 29.3 million bushels. Other important ports were, respectively, Puget Sound (Wash.), Philadelphia, Portland and Falmouth (Me.), Superior (Wis.), Chicago and Duluth.[1]

190. **Imports of Wheat.**—All the countries which consume more wheat than they produce are situated in Europe, with the exception of the Oriental countries, which have recently begun to take supplies of wheat from North America. The larger part of the export of wheat and flour from the United States is taken by Great Britain and Ireland, the Netherlands, Germany, France and Belgium. Great Britain, as the principal importer of wheat, is the arbiter of its price throughout the world. The demand for wheat by Great Britain has increased rapidly during the past fifty years, through decrease in wheat production, through increase in population and in per capita consumption.

191. **Commercial Grades.**—Every important wheat market maintains a system of inspection of wheat and other grains. Wheat is bought and sold by grades and all wheat coming into a market is inspected and the grade determined by the inspector and when leaving this market may be inspected again. A specified charge is made for this service. The weight per bushel is determined in every sample, but other considerations help to fix the grade, as plumpness, soundness, freedom from foreign seeds or mixture with a different type of wheat. Aside from the weight per bushel, fixing the grade is largely a matter of judgment and expertness upon the part of the inspector. The information concerning these grades cannot satisfactorily be

[1] U. S. Treas. Dept., Bu. Stat. Statistical Abst., 1902, p. 305.

conveyed to another except by actual practice. The grades vary in different markets to suit the supply and demand at each particular market. The classes and grades recognized by the Board of Railroad and Warehouse commissioners for the inspection of wheat at Chicago are as follows:

White winter wheat Nos. 1, 2, 3 and 4.
Long red winter wheat Nos. 1 and 2.
Red winter wheat Nos. 1, 2, 3 and 4.
Hard winter wheat Nos. 1, 2, 3 and 4.
Colorado wheat Nos. 1, 2 and 3.
Northern spring wheat Nos. 1 and 2.
Spring wheat Nos. 1, 2, 3 and 4.
White spring wheat Nos. 1, 2, 3 and 4.

Red winter wheat containing a mixture not exceeding five per cent of white winter wheat is classed as red winter wheat. Red winter wheat containing more than five per cent of white wheat is graded according to the quality thereof and classed as white winter wheat. Hard winter wheat corresponds to red winter wheat except that it is of the Turkish variety common throughout the Missouri River Valley. A mixture of Turkish wheat with other varieties of red winter wheat is graded as hard winter wheat. Northern spring wheat must contain at least fifty per cent of hard varieties of spring wheat. A mixture of more than five per cent of white spring wheat in red spring wheat will cause it to be graded white spring wheat. Black sea and flinty fife wheat are in no case graded higher than No. 2 and rice wheat no higher than No. 4. Frosted wheat is not graded higher than No. 4 except that the grade of No. 3 may contain as much frosted wheat as is customary to all wheat damaged in another way. Only a small portion of the wheat of any sort grades No. 1. Most of the wheat dealt in grades No. 2 or No. 3. The following are the rules for grading red winter wheat:

"No. 1 Red Winter Wheat shall be pure Red Winter Wheat of both light and dark colors of the shorter berried varieties, sound, plump and well cleaned.

"No. 2 Red Winter Wheat shall be Red Winter Wheat of both light and dark colors, sound and reasonably clean.

"No. 3 Red Winter Wheat shall include Red Winter Wheat not clean and plump enough for No. 2, but weighing not less than fifty-four pounds to the measured bushel.

"No. 4 Red Winter Wheat shall include Red Winter Wheat, damp, musty or from any cause so badly damaged as to render it unfit for No. 3."

## III. HISTORY.

192. **Antiquity.** — The cultivation of wheat is much older than the history of man. Very ancient monuments, much older than the Hebrew Scriptures, show its cultivation already established. The Egyptians and the Greeks attributed its origin to mythical personages. The earliest Lake Dwellers of Western Switzerland cultivated a small-grained variety of wheat as early as the Stone Age. The Chinese grew wheat 2700 B. C., and considered it a direct gift from Heaven. Wheat is one of the species used in their annual ceremony of sowing five kinds of seeds. Chinese scholars believe it to be a native of their country.

193. **Original Habitat.**—The existence of different names for wheat in the most ancient languages confirms the belief in its great antiquity. It has been asserted that wheat has been found growing wild in Western Asia, but the evidence is not conclusive. The Euphrates Valley is believed by De Candolle to be the principal habitation of the species in prehistoric times. So far as known, wheat was not grown in America before its discovery by Columbus.

194. **Reasons for Culture.**—Its ease of cultivation; its adaptation to a climate favorable to the beginning of civilization; its quick and abundant return; its ease of preparation for use; its abundant supply of nutritious substance; possibly its rapid improvement under cultivation and the fact of its being paniferous, or possessing that special quality which adapts it above any other grain to the making of light bread, were probably some of the reasons which caused primitive man to begin and continue its

cultivation. In addition, its wide adaptation to different soils and climate has made it one of the principal foods of mankind.

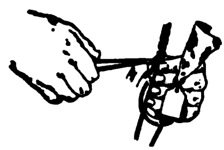
## Practicums.

195. STUDY OF THE SPIKE OF WHEAT.—Request each student to report the following, after examining a head of wheat:

1. Number of spikelets in the spike of wheat.
2. Number of flowers in each spikelet.
3. Number of grains in the whole spike.
4. Determine the number and arrange weight of grains occupying first, second, third and fourth place from rachis.
5. Number of empty glumes in a spikelet.
6. Make a sketch of the beak, shoulder and auricle of the empty glume.
7. How does the flowering glume differ from the palea?
8. How is the spikelet attached to the rachis?
9. Draw the rachis.

The spikes of wheat should be laid between pieces of moistened blotting paper for several hours before handing the students, in order to toughen the parts.

196. METHOD OF CROSS-FERTILIZATION.—In order to effect cross-fertilization, the anthers must be removed from all the flowers on the spike, before any of them have shed their pollen. This can best be done when or before the anthers are slightly tinged with yellow. The labor may be reduced by removing all but one or two dozen flowers. If spikelets on the middle portion of the spike are left and only the two lower flowers of the spikelet, more uniformity in the maturation of the flowers will be obtained, as well as more uniformity in other particulars. After carefully removing the unbroken anthers, the emasculated spike may be protected by wrapping about it a piece of tissue paper and tying it above and below. One to two days later the flowers will open, which may be told by adjacent uncovered spikes. Pollen may now be brought from the variety chosen for the male parent and deposited upon the stigmas of the emasculated flowers. The cross-pollinated spike is again covered, and requires no further attention until ripe.



In the upper illustration operator is removing spikelets which are not to be crossed. In the lower the flowers are being opened to remove the anthers (after Hays).

197. TYPES OF WHEAT.—To familiarize the student with species and subspecies of wheat, give each a couple of spikes and stems of each of the eight species and subspecies, and have him identify by the use of the following outline adapted from Hackel:[1]

*Triticum* L. Genus. Spikes with rarely aborted spikelets, rachis not articulate in cultivated species; lowest one to four spikelets smaller than the others, awnless,

[1] True Grasses, pp. 180-183.

usually sterile. Fertile spikelets inflated or ventricose, two- to five-flowered, fruits one to three. Lowest spikelet closely imbricated; empty glumes broad, one- to many-awned, sometimes a toothed apex; flowering glumes rounded on the back, often navicular, many-nerved, ending in one to several awns; fruit slightly compressed laterally, deeply sulcate, hairy at the apex, free. Embryo with epiblast and three rootlets. Annual. Two poorly defined sections of which one (*Ægilops* L.) is not cultivated.

Section II. *Sitopyros*. Empty glumes sharply keeled. Species three.

A. Terminal spikelet usually aborted; mature palea falling into the parts; lateral teeth of empty glume acute. 1. *Tr. monococcum*.

B. Terminal spikelets developed; palea entire; lateral teeth of empty glume obtuse.

a. Empty glumes chartaceous, shorter than flowering glume; palea as long as flowering glume. 2. *Tr. sativum*.

b. Empty glumes sometimes longer than flowering glume, chartaceous, lanceolate; palea of lowest flower half as long as its glume. 3. *Tr. polonicum*.

1. *Tr. monococcum* L. Spikes compact, articulate, joints separating, spikelets one-awned, usually only lower flowers maturing fruit.

2. *Tr. sativum* Lam. Three races.

I. Rachis articulate at maturity; grain entirely enclosed by glumes, not falling out when threshed.

1*. Spikes loose, almost four-sided when seen from above; empty glumes broadly truncate in front, with very short, obtuse middle tooth; obtusely keeled. a. *Tr. sat. spelta*.

2* Spikes dense, laterally compressed; empty glumes tapering; middle teeth acute; sharply keeled.

b. *Tr. sat. dicoccum*.

II. Rachis not articulate at maturity; fruiting glumes somewhat open; grain falls out easily. c. *Tr. sat. tenax*

a. *Tr. sat. spelta* Hackel. Awned or awnless, hairy or smooth-spiked; white, gray, blue, reddish.

b. *Tr. sat. dicoccum* Hackel. Always awned. Spikes broader on two-ranked side, narrower on imbricated side.

c. *Tr. sat. tenax* Hackel. Four poorly characterized subraces.

1.* Empty glumes distinctly keeled in the upper half, rounded or only slightly keeled below.

* Spikes long, more or less loose, somewhat dorsally compressed.

1′ *Tr. sat. vulgare*.

** Spikes short, dense, distinctly four-sided.

1″ *Tr. sat. compactum*.

2.* Empty glumes sharply keeled at the base.

* Fruit short, thick, not compressed, broadly truncate above.

1‴ *Tr. sat. turgidum*.

** Fruit oblong, narrow, laterally compressed, somewhat acuminate.
1''''' *Tr. sat. durum.*

3. *Tr. Polonicum* L. A very striking species, with large, compressed, mostly blue-green spikes. Spikelets appearing as if cut off transversely, because the third and fourth flowers scarcely reach to the point of the two lower ones; flowering glumes compressed, navicular, many-nerved, awned; fruit 8-12 mm. long.

## METHOD OF DESCRIBING WHEAT VARIETIES.

198. HALF GROWN PLANT IN THE FIELD. Each student should be given a printed or typewritten sheet as indicated below and requested to describe two or more varieties of wheat growing in the field by underscoring the adjective which most nearly applies to the condition found.

1. Color: light green; medium green; dark green; light yellowish green; medium yellowish green; dark yellowish green; light gray green; medium gray green; dark gray green.
2. Leaf blade: average length of ten blades ———.
3. Leaf blade: average width of maximum dimensions of ten blades ———.
4. Leaf blade: erect; ascending; drooping.
5. Leaf blade: smooth; rough; downy.
6. Leaf blade: veins prominent; veins not prominent.
7. Leaf blade: end tapering; end with sides parallel.
8. Leaf sheath: green; green shading to purple.
9. Ligule: 2.5 mm. long; 2 mm. long; ... mm. long.
10. Ligule: white; purple.
11. Auricles: white; green; white with purple tips; purple.
12. Auricles: hairy; partly hairy; smooth.

NOTE: The above practicum and those following are intended to teach a method of describing wheat varieties as first proposed by Cobb and published by Scofield. The student should be referred to The Description of Wheat Varieties, by Carl S. Scofield. U. S. Dept. of Agr., Bu. of Pl. Ind. Bul. 47

199. MATURE PLANT IN THE FIELD. Each student should be given a printed or typewritten sheet as indicated below and requested to describe two or more varieties of wheat growing in the field by underscoring the adjective which most nearly applies to the condition found.

1. Height: average of ten culms to tip of apical gloom, not counting awn if any ———.
2. Vigor of plant: strong; medium; weak.
3. Diameter below spike: average of ten culms ———.
4. Depth of furrows below spike: furrowed; medium; smooth.
5. Upper part of culm: solid; semi-solid; hollow.
6. Wall of culm: thick; medium; thin.
7. Color of culm: light yellow; yellow; purple; bronze.
8. Foliage: scanty; medium abundant.

9. Rust: leaves, per cent ————; culms, per cent ————.
10. Smut: loose, per cent ————; stinking, per cent ————.
11. Spike: erect; leaning; nodding.
12. Spike: beardless; partly bearded; bearded.
13. Shattering: badly; medium; none.

200. Mature Dried Plant in Laboratory. Give each student a printed or typewritten sheet as indicated below and request a description of two or more varieties from dried samples by underscoring the adjective which most nearly applies to the condition found. If opportunity to study varieties in the field is lacking, some of the items given in (199) may be included here.

1. Length of spike: average of five spikes from base of lower spikelet to tip of apical flowering glume, not counting awn, if any ———.
2. Compactness of spike: very open; open; medium; compact; crowded.
3. Shape, side view: tapering towards apex; tapering both ways; uniform; clubbed.
4. Shape, end view: square; flattened with spikelet; flattened across spikelet.
5. Sterile spikelets: No. ———.
6. Awns: length ———.
7. Awns: slender; medium; stout.
8. Awns: parallel; spreading; widely spreading.
9. Awns: deciduous; partly deciduous; persistent.
10. Awns: light yellow; yellow; brown; black.
11. Spikelet: spreading widely; spreading; narrow.
12. Spikelet: number of grains ———.
13. Basal hairs: long; medium; short; wanting: white; brown.
14. Outer glume: light yellow; yellow; bronze; black.
15. Outer glume: hairy; partly hairy; smooth.
16. Width of outer glume: broad; medium; narrow.
17. Length of outer glume: long (as flowering glume); medium; short.
18. Attachment of outer glume to rachilla: firm; medium; weak.
19. Beak of outer glume: long; medium; short.
20. Shoulder of outer glume: broad; medium; narrow: square; sloping; round.

201. The Grain. Give each student a printed or typewritten sheet as indicated below and request a description of two or more varieties by underscoring the adjective which most nearly applies to the condition found.

1. Density: very hard; hard; medium; soft; very soft.
2. Appearance of cross-section: very horny; horny; dull; starch.
3. Weight: of 100 average seeds in duplicate (a) ———— (b) ————.
4. Ratio of length to width: divide length of twenty-five grains by width of twenty-five grains with crease down ———.
5. Shape: straight; curved; pear-shaped.
6. Plumpness: plump; medium; shrivelled.
7. Cheeks: flat; plump; angular.
8. At tip: pointed; blunt.
9. At base: pointed; blunt.

10. Crease: deep; medium; shallow: wide; medium; narrow.
11. Brush: large area; small area: long hairs; short hairs.
12. Color of grain: light yellow; yellow; clear amber; dull amber; clear red; dull red.

202. CLASSIFICATION OF VARIETIES OF COMMON WHEAT. Take preferably fifty varieties of either spring or winter wheat in sheaf and in grain. A desirable plan is to have one thousand grains of each variety in glass vials one inch in diameter and six inches high, taking care to have the vials of clear glass and uniform diameter. The difference in the size of grains can be noted at a glance and all other characters as easily observed as in larger samples.

An agronomy laboratory, showing materials ready for the study of varieties of wheat

Require the student to classify them into eight groups as follows:

| | | |
|---|---|---|
| Bearded | Glumes white | Grains red |
| | | Grains white |
| | Glumes bronze | Grains red |
| | | Grains white |
| Beardless | Glumes white | Grains red |
| | | Grains white |
| | Glumes bronze | Grains red |
| | | Grains white |

The student should note what differences, if any, exist between varieties of the same group as for example in smoothness or hairiness of glumes, and length of straw; and in what cases the varieties are probably synonymous. (89) A written report concerning the best ten varieties as shown by Stations testing varieties in

question may be required. Definite references to proper bulletins should be furnished each student.

203. Relation of Color, Hardness, Size, Specific Gravity and Content of Gluten.—

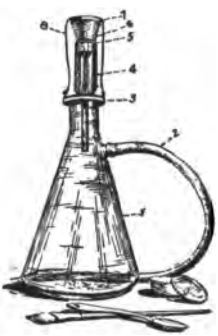
1. Take five varieties of wheat varying as widely as may be in different qualities mentioned, as for example, Fultz, Gold Coin, Rudy, Turkey, Kubanka.

2. Note color and hardness.

3. Find weight of 500 grains.

4. Fill a 50-gram picnometer with benzene and weigh on balance sensitive to 1 mgm. Add twenty grams of wheat and weigh. Add weight of wheat to weight of picnometer and benzene and subtract last weight, which will give weight of volume of benzene equal to volume of grains of wheat. Divide this difference by the specific gravity of benzene, which will give the weight of a volume of water equal to the volume of grains of wheat. To determine the specific gravity of the wheat, divide twenty grams of wheat by the weight of an equal volume of water.

5. To find the relative size of grains, divide the weight of five hundred grains by their specific gravity.



Snyder's apparatus for determining the granulation of flour. 1, Erlenmeyer flask; 2, suction connection; 3, rubber cork; 4, adapter; 5, rubber (tube) packing, making air-tight joint; 6, section of brass crucible overlapping section 7; between these two parts bolting cloth is placed and removed as desired—any size cloth can be inserted; 8, wire clamp holding apparatus in place.

6. To determine content of gluten, take thirty grams of ground wheat, work with water in a round bottomed glass vessel with spatula, and wash off starch after gluten has gotten into a sticky mass, and continue to wash until there is no appearance of starch grains being carried off. To be sure that all the starch is freed from gluten, test washings with potassium iodide; blue color shows the presence of starch. Work mass of gluten in fingers until all water that will run off has been expelled. Weight will give amount of moist gluten. Place in drying oven at 110° C until constant weight is obtained. Weight will give amount of dry gluten. At same time find weight of dry matter in ten grams of ground wheat. Calculate per cent of moist and dry gluten from data obtained.

If there is not time or facilities to carry out No. 6, the instructor may determine the content of gluten in advance and allow the student to compare Nos. 2 to 5 with the results thus obtained.

204. Quality of Flour.—Furnish each student with a sample of high grade and low grade flour and have him determine the following:

1. Character of granulations: Note under a high power microscope (172) whether flour particles are round or angular.

2. Size of particles: By means of apparatus devised by Snyder, determine the amount of flour in twenty-five grams that will pass through bolting cloth Nos. 9 to 20.

3. The color test: Place samples of flour on plate of glass and determine color by means of a series of colored glass slabs.[1]

4. The baker's sponge test: Place in a wide pint porcelain bowl one hundred grams of flour. Dissolve five grams of sugar and five grams of compressed yeast in sixty-five grams of water and stir with steel spatula into flour. Continue to add water and knead until proper consistency is obtained. Note quantity of water required to give equal consistency in both samples. Place dough in cylinders about four inches in diameter graduated into c. c.'s. Set tube in water at 90° F. and determine time required to rise to full height and maximum volume attained. If time permits, allow second rise to occur and note time and maximum volume. The first rise takes about an hour and a half to two hours and the second rise from an hour to an hour and a half. If the per cent of gluten has been determined (203), calculate volume to each gram of gluten.[2]

205. COLLATERAL READING.—

The Basis for the Improvement of American Wheats. By Mark Alfred Carleton. U. S. Dept. of Agr., Div. of Veg. Phys. and Path. Bul. 24, pp. 63-83.

The Structure of the Wheat Grain. By Charles E. Bessey. Neb. Bul. 32, pp. 100-114.

William C. Edgar: The Story of a Grain of Wheat, pp. 111-131. New York: D. Appleton & Co.

Plant Breeding. Willet M. Hays. U. S. Dept. of Agr., Div. of Veg. Phys. and Path. Bull. 29, pp. 44-54.

Grain Elevators. By N. A. Cobb, Dept. of Agr., Sidney, New South Wales, Misc. Pub. 452.

[1] These can be purchased of Eimer & Amend, New York.

[2] For further details see Minn. Bul. 62. (1899), pp. 346-352.

# VIII.

## MAIZE.

### I. STRUCTURE.

**206. Name.**—Columbus found *Zea mays* L. cultivated on the Island of Hayti, where it was called mahiz; hence the name maize. Mahiz, or marisi, is said to be an Arawak Indian word of South American origin.[1] The word corn is used in Europe as a generic term for all cereals, and originally the word meant any hard edible seed, grain or kernel. In England an ear of corn means a head or spike of wheat. Naturally, therefore, the colonists, finding maize cultivated abundantly by the Indians, applied the term Indian corn to distinguish it from other corn. In the United States corn is everywhere understood to mean maize and a Pennyslvania court has ruled that the word corn is a sufficient description of Indian corn. In Latin America "maiz" is the term generally used.

**207. Fodder, Stover and Silage.**—*Fodder,* when applied to maize, is the plant, including the ears, which has been cut and field cured without regard to the manner or thickness of planting or stage of maturity. *Stover* is the residue after the ears have been removed from the fodder. When the whole plant or the residue after removing the ears is placed without curing in the silo, the resulting material is called *silage.*

**208. Relationships.**—The tribe (*Maydeae*) to which maize (*Zea mays* L.) belongs differs quite widely from the tribe (*Hordeae*) to which wheat, rye and barley belong. In the same tribe with maize belong teosinte (*Euchlaena mexicana* Schrad.), a sub-tropical plant sometimes cultivated in the Southern States

[1] Harshberger, J. W.: Maize; A Botanical and Economic Study, p. 88.

for fodder purposes, and gama grass (*Tripsacum dactyloides* L.) which was a rather conspicuous feature of the native herbage of the prairie regions in the central and southern portions of the United States.

The wild prototype of *Zea* has not with certainty been identified. So far as known there is only the one species which includes all the cultivated types and varieties of maize.[1]

Brace roots on Mexican maize grown at Iowa Station farm (after King).

209. **Roots.**—The form and habit of growth of the roots of maize are similar to those of wheat, although modified somewhat in position, due doubtless to the plant being in hills or drills instead of being broadcast. The general tendency is for the roots to grow somewhat horizontally for one or two feet and then turn down more or less abruptly. The position of the roots is modified by the depth of fertile soil and by depth to which the seed bed has been stirred.[2] The indications are that the distribution of roots depends more upon a proper supply of oxygen and water than upon temperature. The following table shows a number of roots at six inches from the plant at different depths in plants one to six weeks old as examined in a black prairie soil at the Illinois Station:

| Depth below the surface | 1888 | 1889 | 1890 |
|---|---|---|---|
| Less than two inches . . . . . | 1 | 0 | 6 |
| Two to four inches . . . . . . | 22 | 31 | 114 |
| Over four inches . . . . . . | 1 | 17 | 59 |
| Total . . . . . . . | 24 | 48 | 179 |

1 For a summary of the evidence concerning the wild prototype of maize, see Maize: A Botanical and Economic Study. By John W. Harshberger. Contributions from the Botanical Laboratory of the University of Pennsylvania, Vol. 1, No. 2.

2 N. Y. State (Geneva) Rpt. 1887, p. 95; 1888, p. 171.

Observations made in Alabama, New York, North Dakota, Iowa and elsewhere, have shown that the roots grow horizontally for some distance from the plant, within four inches of the surface. These lateral roots are very abundant, especially in the early part of the season. Later in the season, however, roots are sent downward in greater number, the lateral roots meanwhile continuing to grow and rebranch, so that in the course of eight to ten weeks the soil between the hills, under ordinary culture, is completely occupied by a dense ramification of roots. One hundred branches have been counted on a piece of maize root fourteen inches long. Many instances have been reported of roots growing four feet deep, and in some cases roots have been broken off at a depth of fifty inches, showing that they must have grown somewhat deeper. Hays reports maize roots eight feet in length, although not in depth. In most soils, however, the amount of root surface below the first two feet is comparatively small. This suggests that the relatively few unbranched roots which descend to greater depth do so to supply the plant with water. The requirements of the plant for water are very great, both because of the large amount of dry matter per acre produced and because the season of active growth is during the hottest portion of the year.

In the early stages of the plant the root growth is rapid. A maize plant one-half inch high has been observed with a root eight inches long; one three inches high with a root thirteen inches long, and two five inches high with roots eleven to twenty-four inches long. Unlike the wheat plant, which throws out a whorl of three temporary or seminal roots, the radicle of the maize plant enlarges and remains prominent, while two or three other roots of lesser size are thrown out. Compared with the lower portion, the stem is very much enlarged at the point where the permanent or coronal roots begin. In a plant thirty days old and twenty-one inches high the stem between the temporary and permanent roots was one-sixteenth of an inch in diameter,

while just above the permanent roots it was three-eighths by five-eighths inch. The majority of the permanent roots begin at about one inch below the surface of the soil, regardless of the depth of planting. Brace roots, however, usually start from the node, one or two inches above ground. The aerial portion is much enlarged, but soon after entering the ground becomes reduced to the size of the other roots. A maize plant forty-three days old and five feet high was found to possess thirty-five roots, eleven of which were brace roots. None of the brace roots had entered the ground more than one and one-half inches. Their total length varied from one and one-half to five inches. An examination of the mature plants shows the brace roots to have grown to considerable depths, thus performing the function of true roots. Variety differences in ability to support the culm and prevent its being blown down have been observed, but this character has not as yet been made of practical value.[1]

210. **Culms.**—The maize plant is the most variable in size of the cereals. The height is reported to vary from eighteen inches in the Tom Thumb pop to thirty feet or more in the West Indies. Individual stalks twenty-two and one-fourth feet high have been reported from Tennessee. From four to twelve feet is a common variation. The height varies not only with the variety but the same variety varies largely with soil and climatic conditions. Along the Mississippi River, south of the fortieth parallel, it is not unusual to see maize growing on which the ears are so high that a man of ordinary height can barely reach them. In the northern latitudes of the United States, as in New England, much maize is so short as to make it necessary to stoop to reach the ears. The circumference of an average maize culm, between the first and second nodes, in a dent or flint variety, will be from three to four and one-half inches. Unlike most of the plants of the grass family, the culm of maize is not hollow, the interior being filled with a soft pith, which does not add mate-

1 Miss. Bul. 33, p. 75.

rially to its strength. The internodes are alternately furrowed on the side next the leaf blade and on the side where the branch or ear may occur. In fact, furrows appear to occur for the accommodation of the branch or ear buds.

The maize plant does not depend alone upon the node for erecting bent culms as in the other cereals and grasses generally, but the walls of the lower internode have a similar power. (378)

The per cent of crude fiber is considerably higher in the outside of the culm than in the pith, thus increasing the per cent of other constituents in the latter. Aside from this, the per cent of ash is higher in the pith, being especially high in potassium and calcium, while the culm wall is notably high in silica.

At the New York Station the rate of growth ranged from three to eighteen and one-half inches per week. Under specially favorable conditions a growth of five inches was recorded in one day.[1] At the Illinois Station an increase in one week equal to 1,300 pounds of dry matter per acre was observed.

211. **Suckers.**—Under conditions of ordinary culture, one seed produces but one culm. When, however, the planting is not sufficiently thick for the existing conditions, the plant may produce one or more branches from its lower nodes, which branches will throw out separate roots. The branches or culms are known as suckers, and usually do not produce ears. They are not desirable because they take plant food and water from the soil without giving any return in grain. Some varieties of maize produce a number of branches from nodes higher up the culm. Ordinarily, however, the maize plant is unbranched except where its one or more ears are produced, the ear being produced at the end of a much modified branch. (214)

212. **Leaves.**—With dent maize grown in Iowa, the number of leaves on a culm varied from twelve to eighteen.[2] Since the

1 C. S. Plumb: Indian Corn Culture, p. 14.

2 Iowa Bul. 2 (1888).

lower leaves die off before maturity, activity at any one time is confined to about twelve. The width of the blade varied from three and three-quarters to five and one-eighth inches. At the Missouri Station the total external leaf surface on twelve living leaves of a single maize plant was found to be twenty-four square feet.[1] As 12,000 plants per acre are not an unusual stand, the leaf surface may be more than a quarter of a million square feet on an acre, or about six times the area on which the plant stands.

At the Michigan Station the leaves constituted somewhat more than a third of the dry matter when the grains were in milk, and a little more than a fifth when the plant was ripe. During this period the percentage of dry matter of culm remained about the same, the decrease in percentage of dry matter in leaves having been offset by a corresponding increase in the ears.[2]

The outer edges of the leaf blade grow faster than the portion next the midrib, giving a wavy effect to the blade and giving it an elasticity which aids it to withstand wind. In the upper portion of the blade, on either side of the midrib, are to be found large wedge-shaped (bulbiform) cells which on filling with water cause the young leaf to unfold and which during drouth cause the leaf to roll, thus reducing the evaporation from the plant. The under surface of the leaf is further protected, also, against transpiration by a strong cuticle. The ligule tightly clasps the stalk, preventing the entrance of water and accompanying dirt between sheath and culm: it also prevents the sheath from rotating upon the culm as in most of the grasses.

213. **Relationship of Grain to Stover.**—Of two stalks bearing the same quantity of grain, the smaller is to be preferred, where grain is the principal object sought. The larger the stalks the more food material necessary to produce them, the more ground

[1] Mo. Bul. 5 (1889).

[2] Mich. Bul. 154 (1898), p. 272.

is shaded, and, consequently, a less number of stalks can be raised per acre.

In some localities the ear may be too high on the stalk to be husked easily. While there are wide variations due to variety, soil, climate and thickness of planting, the weight of field-cured stover has been estimated at about one and one-third pounds for each pound of grain produced. In actual dry matter the yield per acre may be estimated as about equal under ordinary field culture. It has been estimated that for every pound of dry matter produced in the roots and stubble when cut close to the ground, six pounds are produced in the plant above ground.[1]

Dent maize, variety Sibley's Pride of the North. Compare with flint variety upon opposite page. Note that this variety has no suckers and that the husks have completely lost their leaf blades. Plant has been in tassel about two weeks. It is not as mature as the flint variety, hence the ear is relatively small. (One twenty-fourth natural size.)

214. **The Inflorescence.**—The cultivated maize plant bears its carpels and stamens in separate flowers. The staminate flowers borne in a panicle of spikelets at the top of the culm are called collectively the tassel. The carpellate flowers are borne in the

[1] Wis. Rpt. 1892, p. 119. In this connection, see also Mo. Bul. 9.

axils of the leaves, forming upon maturity what is known as the ear. The fruit of the maize plant being borne in the axils of the leaves rather than being terminal is a feature which distinguishes maize from all the other cereals. The difference is more apparent than real. Certain varieties of maize, especially pod maize, sometimes bear carpels upon the tassel of the main culm, and where branches occur bear both stamens and carpels at their end.

It is assumed that wild maize was a branched plant containing perfect flowers (both carpels and stamens) on the terminal tassel and, also, at the end of the branches. Since the plant is wind fertilized and the pollen tends to fall, the carpellate flowers in the terminal tassel would be less perfectly pollenized than those on the branches below. The pollen on the branches would tend to fall to the ground, thus being of little value. The plants which had the greatest development of carpels on the branches and of stamens in the terminal tassel would tend to survive. As the end of a branch became laden with a collection of grains (ear) the short branch would

Flint maize, variety Smut Nose. Compare with dent variety upon opposite page. Note two good ears with rudimentary one below upon main culm, and also the leaf blades upon the husks of the ear. The other three culms are suckers, all having grown from one seed. Plant has been in tassel about three weeks. (One-twenty-fourth natural size.)

best hold the ear from drooping. Thus the culm of the branch (now called the shank) has become a succession of nodes with short internodes. Each node still bears the sheath of the leaf, the blade being much reduced in size or aborted. This collection of leaf sheaths is called the husk. The branch has been telescoped. (211.)

215. **The Tassel.**—The tassel is a spreading panicle generally a foot or more in length in field varieties, with branches usually six to ten inches long. The spikelets extending from base to tip of each branch (rachis) are arranged in clusters of two to four, one usually pediceled, the others sessile, or all sessile, the clusters often overlapping. The empty or outer glumes, about equal, three-eighths to one-half inch long, are stouter and harder than the flowering glume and palea. The latter are about equal and shorter than the outer glumes. They are hyaline and much thinner. Each flower bears three stamens. The anthers are large, nearly as long as the flowering glume. They are attached to the filament on one side near the lower end.

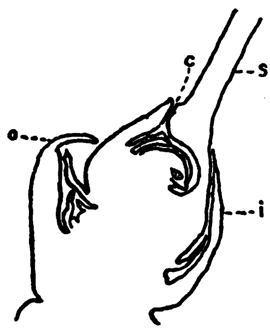
Lazenby estimates that 45,000 pollen grains are produced for each ovule in dent maize.[1] According to another estimate, an average maize plant has seventy-two hundred stamens, containing about eighteen million pollen grains. Assuming two thousand ovules to a plant, there would be nine thousand pollen grains to an ovule.[2] It is held that the staminate flowers usually mature before the carpellate, but they may mature at the same time or later.

216. **The Silk.**—The style, commonly known as the silk, arises at the summit of the carpel. In certain varieties, as pop maize, the scar may be plainly seen on the top of the ripened grain. Since the end of all silks, for the silk to be effective, must protrude beyond the surrounding husk, the silk may be a

[1] Proc. Soc. Prom. Agr. Sc. (1898).

[2] Sargent: Corn Plants, p. 44.

foot or more in length. Near the base of the silk on the side opposite the embryo there is an opening through the wall of the ovulary to which has been given the name stylar canal. It is not known positively whether the pollen tube passes down through the substance of the silk, entering the ovulary by way of the base of the silk, or whether the pollen tube enters the ovulary through the stylar canal. Guignard and others believe the latter to be the case.[1,2] Whether the pollen tube before entering the stylar canal grows down the outside of the silk or whether the pollen grain by some mechanical means reaches the opening to the stylar canal is likewise unknown. After pollination, the silk dries up but persists. When, however, pollination is prevented, the silk grows to unusual size and remains green two or three times as long as normal.



A spikelet of maize before fertilization; *s*, style or silk; *c*, the stylar canal through which, perhaps, the pollen tube enters the ovulary; *i*, inner glume; *o*, outer glume. Enlarged twelve times (after Poindexter).

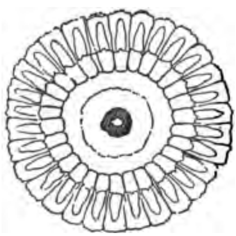
217. **The Ear.**—The ear may vary from one-half an inch to sixteen inches long and may have from four to forty-eight rows in individual ears. A variation of from four to twelve inches in length and from eight to twenty-four rows is not uncommon and may obtain as a variety characteristic.

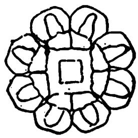
The ear may be looked upon as being formed by the growing together of four or more spikes, each joint of the rachis bearing two spikelets. Each spikelet is two-flowered, the lower one being abortive (214); thus the distinctly paired rows often observed represent a pair of spikelets. The growing together

1 Guignard, L.: La double fecondation dans le mais. Jour. d. Bot. 15: 1-14 No. 2, 1901.

2 Poindexter, C. C.: The Development of the Spikelet and Grain of Corn Ohio Naturalist, Vol. IV, No. 1, Nov. 1903.

of the rachi forms the cob. It is interesting to observe that the development of the cob seems to be in some measure dependent upon the development of the grains. As the tip of the cob develops last, ears are likely to be more tapering where soil or seasonal conditions have been unfavorable. A tapering ear may, therefore, in some instances, indicate a lack of adaptation to the locality in which it is grown.[1]


Thirty rows.


Eight rows.

In the cultivated varieties the glumes and paleae are reduced to small membranous parts around the base of the grains. In the pod maize, however, the glumes are very large, completely enclosing the grains.

The several rachi which make up the cob usually grow nearly straight from butt to tip; hence the two-ranked spikelets result in grains being usually arranged in regular order. These pairs of ovularies are fertilized with such certainty that under normal conditions an odd number of rows never results. Even where the number of rows is less at the tip end than at the butt, the number of rows remains even,—the reduction in number is made by the omission of a piece of the rachis. The case of an ear having twenty-one rows has been reported,[2] but if authentic, is certainly a very rare instance.

218. **The Position of the Ear.**—The position of the ear on the culm (stalk) varies more widely than does the ratio of grain to stover. In some varieties the ears may be too high or too low to be easily husked. When too high, the stalks are more easily blown down. Four feet above ground is a desirable height for ears of medium sized varieties. The shank by which

[1] Torrey Bul. 21, No. 12 (1894), p. 514.

[2] Trans. Mass. Soc. Prom. Agr. 1858, p. 114

each ear is attached to the main culm varies in length. The shorter length, holding the ear in position more firmly, is generally accompanied with a more compact husk, thus better protecting the ear from weather or the attacks of birds and insects. In sections where damage is liable to occur from excessive rainfall, the tip of the ear should hang downward. In the Southern States, if the tip of the ear points upward, rain will enter between the husk and ear and being held there a few warm days will cause the grain at the butt to sprout or rot.

219. **Characteristics of Ear.**—The physical characters of an ear of maize may, in some measure, indicate the yield, maturity, keeping quality and vitality, as well as its purity or trueness to type. By an examination of the split grain some indication of the composition may be obtained. (258) As in all plants and animals, however, the hereditary or reproductive power of ears of similar outward appearance may differ widely. (43) This is especially true of maize, since being wind pollenized, the male parent is unknown. The physical development of the ear is greatly influenced also by its environment.

220. TERMS DESCRIPTIVE OF EAR.—Grains are usually of the same character throughout the ear, or *unikernelled*, but in case of crosses between two types may have two forms or be *bikernelled*. A bikernelled variety from Chile has been figured by Bonafous.

The ear may be *cylindrical* or *cylindraceous*, cylindrical for a portion of its length; tapering, distinctly tapering or slowly tapering, representing different degrees of decrease in diameter from butt to tip. In some varieties the ears are long and slender; in others short and thick; or the ear may be flat.

The grains may be *even at butt* with plane line of cob; or may be *shallow rounded*, *moderately rounded* or *deeply rounded* at the butt.

The ear may taper toward the butt through a flattening of the grains as if pressed down from above, *depressed at butt*, or through a decrease in the diameter of the cob, *compressed at butt;* or through a shortening of the length of grains, *depressed-rounded at butt;* or through both a shortening of the grain and a decrease in the cob, *depressed-compressed at butt*. Or the ear may be *enlarged at butt* by a more or less openness between rows; or *expanded at butt* through increase in number of rows. When space between pairs of rows extends to cob, it is *open at butt*. In some cases of eight or less rowed varieties the rows throughout the ear are in distinctly defined pairs, or *distichous*. The rows may be *rectilinear*, *spiral* or *irregular*.

The tip characters are quite variable within varieties, but a single terminal grain

distinctly projecting is a character of decided permanence in the group of cap flints extensively grown in Connecticut and Rhode Island.

The furrows, or *sulci*, between rows may be absent, apparent, narrow, distinct, or very distinct.

Grains may be *firm*, *loose* or *mosaic-like*, when through pressure their edges become faceted. The grains may be at right angles to cob, *upright*; leaning forward, *sloping*, or may slope forward with apex slightly overlapping, *imbricated*.

The ear stalk may be nearly or quite the diameter of the cob, *large*, or about half the diameter of the cob, *medium*, or one-third the diameter or less, *small*. (243)

221. **Two-Eared Varieties.**—Under ordinary conditions of culture, and particularly with dent varieties, only one ear is produced on each stalk. In some types, as in pop and sweet varieties, the tendency to produce several ears is quite marked. The tendency is more marked in flint than in dent varieties in ordinary field culture. Bailey raised thirty-four ears from one seed of *Zea canina*,[1] twenty-five being on the main stalk. Sturtevant has raised twenty-three ears from one grain of flint maize, and reports as claimed from twelve to nineteen ears per stalk in pop maize; ten or more in flint maize and six to fourteen in dent maize.

The thickness of planting, soil and season influence the number of ears per plant. By varying the number of grains per hill from one to five in the case of Waushakum flint maize, Sturtevant varied the number of ears from 4.6 to 1.2 per plant.

"Among the many varieties which have been tested at the station those which produce usually one ear to the stalk have given smaller yields than those which have produced a greater number of ears. It is quite possible, however, to increase the number of the ears at the expense of the total yield of grain. Three years ago a correspondent sent us a stalk bearing seven ears, and an accompanying letter offered a supply of the seed for twelve dollars a bushel. A workman was sent to one of the station fields with orders to bring the first five stalks he could find, each of which had two ears. Both lots were dried thoroughly before shelling, and in every case the grain from the stalks bearing two ears outweighed that from the seven-eared stalk. We have found no variety which produces uniformly one, two, or any other number of ears, but have found the ears to vary from 86 to 537 on one hundred stalks, counted as they stood in the rows. The best yields have come from those varieties which produce from 175 to 200 ears to one hundred stalks, and we have endeavored to find or to produce a variety which should have uniformly two ears on

1 A variety of pop maize.

each stalk, as the nearer we have been able to approach such a variety, the greater has been the yield of grain per acre."[1]

No two-eared dent variety has ever been produced which has become extensively grown or widely popular. It has not been shown in what way it is easier for a stalk of maize to elaborate the material for two ears than it would be to produce the same grain in one ear. When harvested by hand, varieties bearing but one ear on a stalk are to be preferred, unless the two or more eared varieties yield an appreciably larger quantity of grain. On the other hand, when fed to cattle without removing from stalk, two smaller ears might be preferred. For silage, the total yield of grain would be the only consideration.

222. **Barren Stalks.**—A varying percentage of the stalks of the field are barren—do not bear any ears. The percentage of barren stalks on a given soil varies with the thickness of planting and the season. Barrenness does not seem to be a variety characteristic. It seems to be largely the result of environment. If it were an hereditary characteristic the fact that the stalks are barren would tend to eliminate them.

223. **The Grain.**—The maize grain has the same general structure as the wheat grain. (60) While quite variable, it is characterized by its large size as compared with the seed of any other species of the grass family. The weight of 100 grains may vary from three grams in Miniature pop to 100 grams in Cuzco soft.[2] It is also greatly different in shape from the grain of the other cereals, the furrow on the side opposite the embryo being entirely wanting. In most varieties, the grain is flattened and more or less triangular or oval in shape with its lateral diameter greater than the diameter parallel with the axis of the cob, while some varieties have spheroidal and others conical grains.

Viewed from its broader surface, the grain may be broad above and taper by straight lines to a very narrow base, *cuneate wedge-shaped;* or may be broad above

[1] Miss. Bul. 33 (1895), pp. 75-76.

[2] E. L. Sturtevant: Varieties of Corn. U. S. Dept. of Agr., Office of Expt. Sta. Bul. 57, p. 8.

and taper by curved lines to a narrow base, *rounded cuneate;* or may be broad above, less broad below, connected by straight lines, *truncate-cuneate*; or sides of grain may be parallel in the upper portion and thence taper to a more or less broad base, *shoe-peg form;* or may be nearly or quite as broad at base as at summit, *rectangular;* or the corner may be rounded both above and below, *rounded corners.* The summit of the grain may be *rounded* or *flat;* may end in a long narrow tip, *rostrate;* or a short abrupt point, *mucronate.* On the other hand the summit of the grain may be depressed, *dented.* The *indentation* may be round or cup-shaped, *dimple dented;* or longer than broad, *long dimple dented:* or the sides may be pinched and parallel, *crease dented;* or the two sides may be pinched together closely and project upward and forward, *pinched dented;* or with the last condition there may be a more or less ragged projection from the summit on the side next the embryo, *ligulate dented.*

As a variety characteristic, depth is much more constant than width of grain, the former being a quite constant character.

224. **Shape of Grain Upon Maturity.**—Sturtevant states that each of the five types of maize furnishes three well-defined subtypes, with parallel relationship throughout. Thus, subtype A, the grain broader than deep; subtype B, the grain as broad as deep; subtype C, the grain much deeper than broad.

"All my collections concur towards the belief that climatic relations are more evident in these subspecies (subtypes) than in the species (types) themselves. With the possible exception of the dent corns and the starchy-sweet, for which as yet but one locality is known, the climatic range and adaptability seem about the same, but in the subspecies (subtypes) there is diversity, A being for climates of short season, C for long seasons, while B in general is intermediate; although a climate suitable for C can grow A and B."[2]

In a study of 168 varieties, he classifies types and subtypes as follows:

| Type | Subtype A | Subtype B | Subtype C | Totals |
|---|---|---|---|---|
| Pop maize . . . . . | 4 | 5 | 19 | 28 |
| Flint maize . . . . . | 27 | 9 | 8 | 44 |
| Dent maize . . . . . | 8 | 2 | 38 | 48 |
| Soft maize . . . . . | 7 | 5 | 2 | 14 |
| Sweet maize . . . . . | 14 | 12 | 8 | 34 |

[2] Bul. Torrey Bot. Club, Vol. XXI (1894), No. 8 pp. 320-323.

# IX.

## MAIZE.

### I. STRUCTURE (CONCLUDED).

225. **The Embryo.**—The scutellum and vegetative portion with its miniature leaves and roots can readily be seen with a low power microscope. (61) The embryo situated on the side toward the tip of the ear, while variable in size, is relatively large, variations of from 7.7 to 15.7 per cent having been reported.[1] In an average ear, not far from one-eighth of the grain is embryo. (60) The embryo is characterized by high percentage of ash, protein and fat. The following per cents in the water-free substance of the embryo have been reported:[2]

| | Ash | Protein | Fat |
|---|---|---|---|
| Voorhees . . . . . . . . | 10.0 | 19.5 | 26.7 |
| Balland . . . . . . . . | 7.9 | 15.3 | 39.9 |
| Hopkins . . . . . . . . | 9.9 | 19.8 | 34.8 |

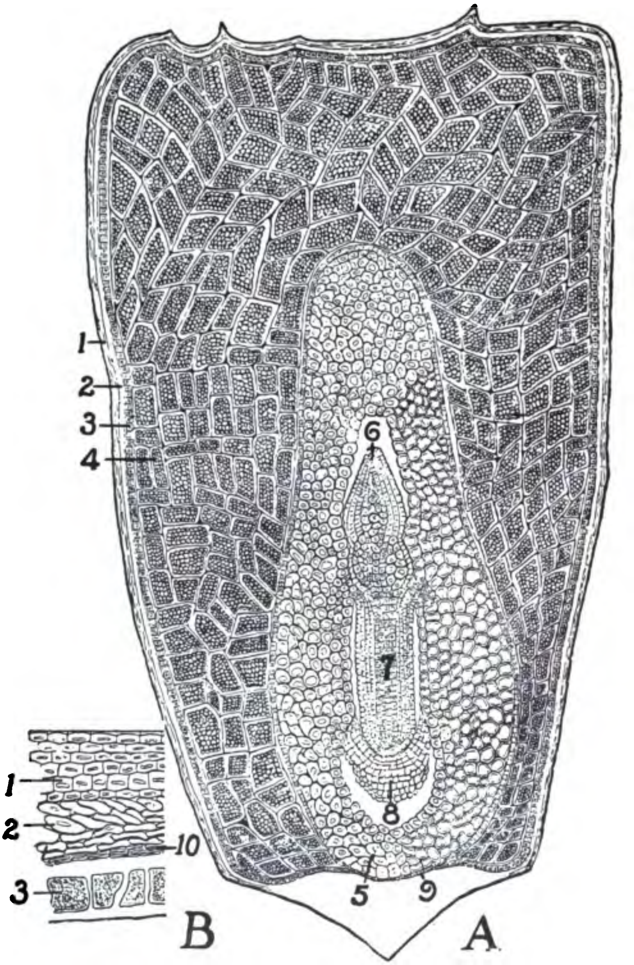
In dent maize the embryo contains about twenty per cent of the protein, seventy-five per cent of the ash and eighty to eighty-four per cent of fat of the whole grain.[3]

226. **The Endosperm.**—A section of the endosperm varies from snowy white to translucent in appearance. The difference between the types or subspecies of maize is in part based upon the relative amounts and arrangements of the white and translucent or corneous endosperm. When cross-sections of the

[1] Ill. Bul. 55, pp. 234-235.

[2] Ill. Bul. 53, p. 140; 87, p. 83.

[3] Ill. Bul. 87, pp. 90-91.




A, an enlarged longitudinal section of maize. The internal structure is diagrammatic inasmuch as about 100 times the number of cells in outline (ten times in diameter) occur in the grain. 1 and 2 show the pericarp; the testa is not shown in A, but is shown in B 10. The nucellus is wanting. 3, aleurone layer; 4, cells of the endosperm; 5, scutellum; 6, plumule; 7, primary root; 8, its root-sheath; 9, a row of cells similar in appearance to aleurone layer but smaller. B, section more highly magnified; shows pericarp composed of two layers; 1, epicarp; 2, endocarp. (The author.)

maize grain are examined under the microscope, no material difference in structure is noticeable. This has led to the suggestion, not positively proven, that the difference between the white and translucent portions of the endosperm is a difference in density analogous to the difference between snow and ice. The difference is readily noted in pop maize before and after popping.

Hopkins reports finding corneous endosperm to contain two per cent more protein than the white endosperm in a dent variety, and makes this the basis of selecting strains of maize for high protein.[1] The question may be raised whether the higher percentage of protein found in the corneous endosperm may not be due to lack of complete separation from the aleurone layer. On the other hand, a somewhat similar condition exists in the endosperm of wheat. (62) Analyses of dent, flint, pop and soft varieties of maize in which there are wide differences in the density of the endosperm do not show material differences in the per cent of protein in the whole grain.

The endosperm occupies about seventy-three per cent of the grain, contains about sixty per cent of the protein, four per cent of the fat, twelve per cent of the ash and about eighty per cent of the carbohydrates, principally starch, of the whole grain.

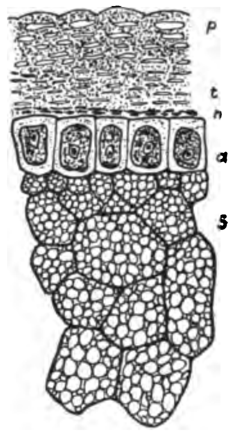
The endosperm contains six to ten per cent of protein, eighty-nine to ninety-three pèr cent of carbohydrates and usually less than half a per cent each of ash and fat. It appears probable that the fat found in the endosperm on analysis may be there through absorption from embryo and aleurone layer, since the per cent of fat in endosperm is found to increase with the age of the grain.[2] In sweet maize the starch has been changed in part to sugar.

227. **The Aleurone Layer** is relatively larger than in the wheat grain, comprising from eight to fourteen per cent of the

1 Ill. Bul. 87, pp. 83-84.

2 Ill. Bul. 87.

maize grain; otherwise it does not differ materially in structure from that of wheat. (63) It contains a slightly greater percentage of protein, considerably greater percentage of carbohydrates and a much less percentage of ash and fat than the embryo.



Cross section of the outer portion of a grain of maize; p, pericarp; t, testa or integuments; n, nucellus; a, aleurone layer; s, endosperm (adapted from Webber).

228. **The Hull.**—In dent maize the hull, including the cap at the base of the grain, constitutes, according to Hopkins,[1] about seven per cent of the grain.

The hull is easily removed from the aleurone layer after soaking in hot water for fifteen minutes. The pod or pericarp, the integuments or testa, and the nucellus or perisperm, which constitute the hull, are not easily separable and cannot be distinguished except upon microscopic examination. (67) In the ripened grain the pericarp forms the larger part of the hull, the testa being compressed and the nucellus much reduced.[2] While under the microscope, the hull appears to be composed chiefly of cell walls or cellulose, Voorhees[3] reports the following composition of the dry substance: Ash, 1.3; protein, 6.5; fiber, 16.2; nitrogen-free extract, 74.4; fat, 1.6. The nitrogen-free extract of the hull appears to be largely gum (pentosan) rather than starch.

229. **Color.**—A very large variety of colors is known to occur in the grain of different types of maize. The most common colors of all types except sweet maize are yellow or white or some shade between. In this case the color is due to that of the endosperm and possibly also the aleurone layer, but is not

[1] Ill. Bul. 87, p. 83.
[2] Iowa Bul. 54 (1901), p. 132.
[3] Ill. Bul. 53, p. 140.

due to the hull, which is translucent and merely transmits the color from the enclosed material. In blue, purple and black of the soft and sweet types the color has been shown to be in the aleurone layer.[1] In the case of the red color often occurring in dent varieties the color is in the hull, as can readily be seen upon its removal. This colored hull may overlie a yellow or a white endosperm. The continued appearance of red ears in yellow or white varieties of dent maize, although such ears are seldom used for seed, is an interesting phenomenon not yet satisfactorily explained, although sometimes claimed to be due to atavism. By selection the red color may become fixed.

There is no evidence that color affects composition or feeding quality. White varieties are more common in the southern portion and the yellow varieties are more common in the northern portion of the United States. The Mississippi Station in 1895 compiled the yields of white and yellow varieties at seven stations in the central and southern Mississippi Valley. In 1,267 tests with 490 varieties, the average yield of 217 white varieties was found to be 2.5 bushels per acre in excess of the yield of 273 yellow varieties. At only one of the stations (Indiana) have the yellow varieties given the better yield.

"In connection with the tabulation of the records of corn yields at different stations a careful examination was made of the reported yields of wheat and oats, and, without going into details, it may be stated that in both the white varieties have given the heavier yields."[2] (386)

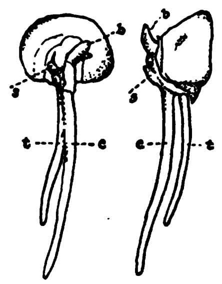
This difference in the case of maize is probably due to the more southern origin and later maturity of the white varieties as compared with the yellow varieties rather than to any inherent influence due to color.

230. **Abnormal Growths.**—The maize plant is subject to numerous abnormal changes. Among these may be mentioned tassel grains, one or more ears at nodes of branch in addition

1 Webber, H. J.: U. S. Dept. of Agr., Div. of Veg. Phys. and Path. Bul. 22.

2 Miss. Bul. 33 (1895), p. 69.

to terminal ear, staminate flowers on cob, staminate flower or even tassel at end of ear or between two separate ears on the same axis, branching cobs and hence ears in a variety of forms, two grains in a single cupule or alveolus, embryo face reversed or sidewise, two embryos in one grain, variegated color in leaves, and red husks.



Two embryos in one grain of maize; b, larger plumule; s, smaller plumule; c, larger primary root; t, smaller primary root (after Shrenk).

II. COMPOSITION.

**231. Grain.**—While it has been shown that considerable variation may be found in the composition of individual ears of the same variety of maize, the average composition of the grain of all varieties and of dent and flint varieties is practically identical. The variation in sweet maize is doubtless due to the relatively small development of the endosperm. Aside from sweet varieties, the rather striking difference in appearance and physical structure is apparently not due to chemical composition.

The following is a compilation of American analyses of the grain of all varieties of maize and of the three principal types:[1]

| | All varieties | Dent | Flint | Sweet |
|---|---|---|---|---|
| Number of analyses | 208 | 86 | 68 | 26 |
| Water | 10.9 | 10.6 | 11.3 | 8.8 |
| Ash | 1.5 | 1.5 | 1.4 | 1.9 |
| Protein (N x 6.25) | 10.5 | 10.3 | 10.5 | 11.6 |
| Crude fiber | 2.1 | 2.2 | 1.7 | 2.8 |
| Nitrogen-free extract | 69.6 | 70.4 | 70.1 | 66.8 |
| Fat | 5.4 | 5.0 | 5.0 | 8.1 |

**232. Fodder and Stover.**—The following table gives the

1 U. S. Dept. of Agr., Office of Expt. Sta. E. S. B. 11.

average of ninety-nine American analyses of silage, thirty-five of maize fodder and sixty of maize stover:

| | Silage | | Fodder | | Stover | |
|---|---|---|---|---|---|---|
| | Fresh | Water-free | Field cured | Water-free | Field cured | Water-free |
| Water | 79.1 | ... | 42.2 | ... | 40.1 | ... |
| Ash | 1.4 | 6.6 | 2.7 | 4.7 | 3.4 | 5.7 |
| Protein (N x 6.25) | 1.7 | 8.0 | 4.5 | 7.8 | 3.8 | 6.4 |
| Crude fiber | 6.0 | 28.7 | 14.3 | 24.7 | 19.7 | 33.0 |
| Nitrogen-free extract | 11.1 | 53.0 | 34.7 | 60.1 | 31.9 | 53.2 |
| Fat | 0.8 | 3.8 | 1.6 | 2.8 | 1.1 | 1.7 |

The average composition of the water-free substance of the sixty samples of maize stover is almost identical with the average composition of sixty-eight samples of timothy hay except a somewhat higher percentage of fat in the latter and a corresponding decrease in the nitrogen-free extract.

233. **Water.**—The per cent of water in both the grain and stover of maize when field cured is extremely variable. When the ears have dried in a crib for a year, the grain will contain under ordinary conditions from ten to eleven per cent of water, but at the time of husking it contains very much more. For example, the Illinois Station found, during 1888, 1889 and 1890, the average per cent of water in varieties of different maturities to be as follows:

| | No. of varieties tested | Av. per cent of water |
|---|---|---|
| Early maturing varieties | 44 | 17.1 |
| Medium maturing varieties | 103 | 21.3 |
| Late maturing varieties | 45 | 26.4 |
| Non-maturing varieties | 23 | 36.8 |

On this basis 1,000 bushels of medium maturing maize would lose, upon becoming thoroughly air-dry, a weight of water equivalent to 115 bushels of shelled maize. If this 1,000

bushels of shelled maize could be sold for fifty cents when gathered, it would be necessary to get fifty-seven cents a bushel when thoroughly air-dry in order to get the same amount for it.

Different varieties vary greatly in regard to the percentage of moisture which they contain. Two varieties of maturing maize have been grown the same season which contained sixteen and thirty-four per cent of water respectively. In the former case, 1,000 bushels of shelled maize when husked would make 945 bushels when air-dry, while in the latter case 1,000 bushels would make only 740 bushels when air-dry. In the first it would take seventy pounds of ears as husked to make a bushel of air-dry shelled maize, while in the last instance it would take ninety-seven pounds of ears to make a bushel when air-dried. The weight of maize as husked does not, therefore, indicate accurately its food value.

The per cent of water in field cured fodder has been found to vary from twenty-three to sixty per cent and in field cured stover from fifteen to fifty-seven per cent, thus greatly modifying the pounds of dry substance per ton and consequently the feeding value per ton of field cured substance. At the Connecticut Station[1] field cured maize fodder was placed in the barn giving perfect shelter November 11th, when it contained twenty-seven per cent of water. On February 8th, after much warm and damp weather, it contained fifty-four per cent of water. Thus maize fodder which weighed five tons when put in storage in November weighed eight tons three months later. This is probably unusual, but it shows the possibility of variation of weight due to atmospheric conditions.

The water in silage has been found to vary from 62.4 to 87.7 per cent. In the first instance a ton of silage would contain more than three times as much dry matter as the latter. When the practice of putting maize in the silo was first started, it was the custom to harvest at a much earlier period of growth than at present. The average of 79.1 per cent of water in silage

1 Conn. Rpt. 1878, p. 64.

given in table (232) is based entirely upon analyses made prior to 1890. It is probable that much of the silage at the present time contains seventy per cent or less of water. Silage at the Wisconsin Station[1] in 1893 contained 64.3, and in 1894, 70.7 per cent of water. In an experimental sample the per cent of water in the maize plant when it was put into the silo was 68.9, while when taken out it was 71.2 per cent. It thus appears that the loss of dry matter in silage is greater than the loss of water.

234. **Ash.**—The maize grain is characterized by a comparatively low percentage of ash. The ash appears to be principally phosphates of potassium and magnesium.[2] The ash contains approximately fifty per cent of phosphoric acid ($P_2O_5$), thirty per cent of potash ($K_2O$), and fifteen per cent of magnesia ($MgO$). The extremely small amount of lime ($CaO$) present, about two per cent, has an important bearing upon the feeding value of maize when fed to growing pigs exclusively or only in connection with milk. Schweitzer found that the maize plant removed from an acre of land 219 pounds of ash and 135 pounds of nitrogen. One-fourth the ash and one-half the nitrogen was removed by the ear.[3]

The Massachusetts Station has found the fertilizing constituents in air-dry substance to be as follows:

| | Grain, per cent | Whole ear, per cent | Stover, per cent |
|---|---|---|---|
| Water | 10.00 | 9.00 | 28.20 |
| Nitrogen | 1.82 | 1.41 | 1.12 |
| Potassium oxide | 0.40 | 0.47 | 1.32 |
| Sodium oxide | 0.03 | 0.06 | 0.79 |
| Calcium oxide | 0.03 | 0.02 | 0.52 |
| Magnesium oxide | 0.21 | 0.18 | 0.26 |
| Phosphoric acid | 0.70 | 0.57 | 0.30 |

1 Wis. Rpt. 1895, p. 276.

2 Ill. Bul. 53, pp. 157-159.

3 Mo. Bul. 9, p. 23.

235. **Protein.**—In the analyses of the 208 air-dry samples including all varieties, the protein (N x 6.25) was found to vary from seven to 15.3 per cent. The usual limit of variation lies between eight and twelve per cent.[1]

Osborne[2] has studied the proteids of the maize grain and has distinguished them according to their solubilities as follows:

"*a* Proteid, soluble in pure water, having some of the properties of proteose.

"*b* Globulins, insoluble in pure water, but soluble in salt solutions.

"*c* Proteid, insoluble in water and salt solutions, but soluble in alcohol of 60 to 99 per cent.

"*d* Proteid matter, insoluble in water, salt solutions and alcohol, but soluble in dilute alkalies and acids."

The most important of these compounds, both on account of its quantity and because it is a characteristic of the maize grain, is the proteid soluble in dilute alcohol, called zein.

No proteids are found in the maize grain which give to its meal the properties which gluten (mixture of gliadin and glutenin) gives to wheat flour. Zein in maize corresponds in some of its chemical properties to gliadin in wheat, but it is neither sticky nor plastic.

236. **Carbohydrates.**—The chief constituent of the carbohydrates of the maize grain is starch, which may constitute sixty-five per cent of the total dry substance. In the manufacture of starch, fifty-five per cent of commercial starch may be obtained from the water-free grain. Besides the starch, the carbohydrates consist of two per cent of fiber, five per cent of gum (pentosans), and small quantities of sugar (sucrose and dextrine).

237. **Fat.**—The fat of maize is fluid at ordinary temperatures, solidifying at —36° F., and is hence known in commerce as corn oil. It is composed principally of linolin and olein and has a specific gravity of about .925.[3]

1 U. S. Dept. of Agr., Yearbook 1901, p. 304.

2 Conn. Rpt. 1896, p. 391.

3 Ill. Bul. 53 (1898), p. 170.

# X.

## MAIZE.

### CLASSIFICATION AND VARIETIES

238. **Species.**—No wild species belonging to the genus *Zea* having with certainty been identified, all the knowledge we have of maize is obtained from its cultivated types, all of which have been considered as coming from one species (*Zea mays* L.). Apart from pod maize, there are five types or classes which are readily recognizable and when kept pure breed true to type. Although the different types cross readily, intermediate types are not common. The difference in these types is due primarily to the arrangement and character of the endosperm, although accompanied with and resulting therefrom are marked variations in the shape of the grain. (226)

If a dent maize grain is split through its two longest diameters, the endosperm will appear to consist of two parts. In the central part the endosperm will appear white, while on either side it is glossy or corneous (horny). Sturtevant first pointed out the relation between the character of the endosperm and the five types of maize. The several types he has called agricultural species and proposed Latin names for them as follows:

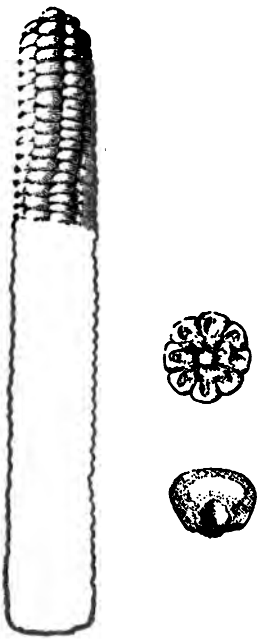
1. Pod maize (*Zea tunicata*).
2. Pop maize (*Zea everta*).
3. Flint maize (*Zea indurata*).
4. Dent maize (*Zea indentata*).
5. Soft maize (*Zea amylacea*).
6. Sweet maize (*Zea saccharata*).

In this book these proposed species will be referred to as the types of maize, and variations within these types will be called varieties.

239. **Pod Maize.**—In this type of maize each grain is covered with a husk in addition to the ear itself being so covered. The plant is excessively leafy, the tassels usually heavy and inclined to produce grains. The plant suckers abundantly. The grains may be of any of the types of maize hereafter described, suggesting that this was the primitive type from which they have been derived, and also, that the differentiation into these types occurred before the podded character became abortive. Reversion is now occasionally seen in cultivated forms. Pod maize is rarely grown even as a curiosity.

Pod maize: one-third natural size.

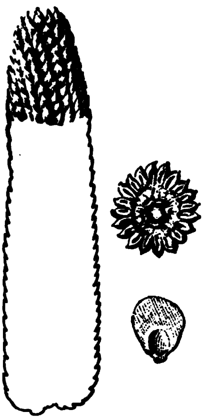
240. **Pop Maize** is that type in which all or almost all of the endosperm is glossy or corneous. Sometimes, perhaps usually, there is a thin layer of white or soft endosperm around the embryo. The grain is usually an elongated oval in outline and extremely hard. The only type with which it can be confused is the flint. The small size of the grain and its property of "popping" makes iden-



Flint maize: ear one-third natural size; grain about natural size.

tification certain. When the dry grain is exposed for a short time to a high temperature, it explodes into a snow-white fluffy palatable mass, the endosperm being everted about the embryo and hull. This property of popping is connected with the density of the endosperm. A small amount of white endosperm does not unfavorably affect popping, but if the white portion is in excess, as in flint maize, the corneous portion explodes without everting the endosperm.

The varieties of pop maize may be divided into two groups, rice and pearl, with the golden as a rather distinct type of the pearl. The rice pop has a very pointed grain at the top, with a tendency to have the grains imbricated instead of side by side and to have the ears cone-shaped. In the pearl pop the top of the grain is smooth and rounded; the grains are compactly arranged upon the cob and are very dense and lustrous in appearance. The ears are cylindrical.



Pop maize: ear rice variety, one-third natural size; grain pearl variety, about natural size.

The plant of pop maize is said to vary with variety, climate and soil from eighteen inches to twelve feet; the usual variation being from five to seven feet. The tendency to bear many ears is strongly marked and the plant is much subject to sports. The ears vary from one to eight and a half inches; usually from four to six inches in length and from one to one and a half inches in diameter. Variations from eight to thirty rows are reported, with twelve to sixteen rows the most common. An ordinary weight is from three to four ounces per ear.

The following table gives weight and dimensions of the grain of four varieties of pop maize:

**Size of Grain of Pop Maize.**

| | White rice | Red rice | White pearl | Queen's golden |
|---|---|---|---|---|
| Weight of 100 grains in grams | 11.7 | 8.6 | 10.9 | 15.2 |
| Length in inches . . . | 0.38 | 0.38 | 0.30 | 0.35 |
| Width in inches . . . | 0.19 | 0.17 | 0.23 | 0.25 |
| Thickness in inches . . | 0.16 | 0.15 | 0.15 | 0.16 |

The white rice, nearly a mean between the red rice and the Queen's golden, contained about 4,000 grains to the pound. It would thus take about three pounds of this variety to plant an acre. The rice pops are nearly square in cross section, while the pearl and golden are considerably wider than thick.

Pop maize has been reported from Ottawa, Canada, in North America to Peru in South America, and the evidence indicates a prehistoric culture.[1] At present it is extensively grown for human consumption when popped. The season in the United States is reported for different varieties and climates from seventy to 146 days; usually from ninety to 135 days. The white rice variety is most commonly used by commercial growers.

241. **Flint Maize** is that type in which the split grain shows the embryo and the white endosperm with the glossy endosperm surrounding. The position of the glossy endosperm usually prevents the grain from denting, but when glossy endosperm is thin, the shrinkage of the white endosperm may cause a slight dent. The internal structure serves to distinguish it from the dent type.

The plant varies in height from four to nine feet; usually from five to eight feet. The tendency to be two-eared is considerably stronger than in the dent varieties. As compared with dent varieties, the ears are longer relative to their diameter and are rather more cylindrical, with often a tendency to enlargement at the butt. Ears vary in length from four to twelve, even six-

[1] U. S. Dept. of Agr., O. E. S. Bul. 57, pp. 15–16.

teen, inches; usually seven to ten inches, with specimen ears twelve inches long not uncommon. The diameter varies from one and one-quarter to two inches; usually from one and three-eighths to one and five-eighths inches. The number of rows on the ear varies from eight to sixteen, with eight rows the most common. Twelve-rowed varieties are more common than ten-rowed. A good ear of an eight-rowed variety will weigh from six to seven ounces.

The grains are hard, smooth, and more or less oval, with usually white or golden orange grains, although purple, brown and copper red sometimes occur. In the eight-rowed varieties the typical grain is one-half inch broad by three-eighths inch deep; when more than eight-rowed, three-eighths inch broad and deep; in thickness, all are about one-sixth of an inch. The average weight of 100 grains of an eight-rowed variety is about thirty-three grams, or about 1,400 to the pound.

This type is reported maturing at 50° north latitude.[1] The season varies from ninety to 140 days, 100 to 120 days being the most common. On account of its early maturity, this type is largely and principally grown in the New England States, New York State, Canada and regions of similar climatic conditions for field purposes; rarely a variety is grown for garden purposes.

Following is a list of varieties of flint maize recommended principally for grain production by the stations indicated, including, where possible, the color of the grain of each and the number of years tested:

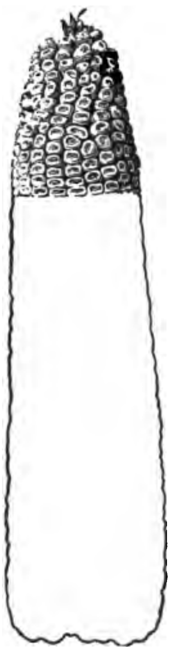
[1] U. S. Dept. of Agr., O. E. S. Bul. 57, p. 16.

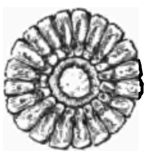
**Table Containing Varieties of Flint Maize Recommended by Various Stations.**

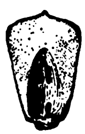
| Station | Authority (Bulletin) | Variety | Color | No. years tested |
|---|---|---|---|---|
| Canada | | | | |
| O. A. C. & E. F. | Rpt. 1902 | King Phillip | Y | |
| | | Longfellow | Y | |
| Kansas | 64 | King Phillip | Y | |
| Nevada | Rpt. 1891 | Canada Yellow[1] | Y | |
| New Hampshire | 92 | Sanford | W | |
| North Dakota | Rpt. 1902 | French Squaw No. 32 | W | |
| | | Gehu No. 123 | Y | |
| | | North Dakota No. 148 | W | |
| South Carolina | 61 | Yellow Flint Corn | Y | |
| | | (On thin upland) | | |
| Oregon | 35 | King Phillip | Y | |
| South Dakota | 24 | King Phillip | Y | |
| | | Smut Nose | W | |
| Utah | 66 | White Flint | W | 10 |
| | | Angel of Midnight | R | 10 |
| | | North Dakota | W | 7 |
| | | Golden Dewdrop | Y | 7 |
| | | Squaw Corn | W | 7 |
| | | King Phillip | Y | 9 |
| | | Long Yellow Flint | Y | 10 |
| Vermont | Rpt. 1890 | Thoroughbred White Flint | W | |
| | | Waushakum | Y | |
| | | Sanford | W | |
| | | Orange County White | W | |
| | | Longfellow | Y | |
| | | Milliken's Prize | Y | |
| | | Early Demond | O | |
| | | Canada Twelve-rowed | Y | |
| | | Angel of Midnight | R | |
| Wisconsin | 19 | King Phillip | Y | |
| Wyoming | 22 | Angel of Midnight | R | |
| | | Rideout Corn | Y | |

[1] Did not ripen grain.

242. **Dent Maize** is that type in which the split grain shows the embryo, the glossy endosperm on each side, and the white endosperm extending to the top. The grain is indented on the top, evidently because the soft endosperm shrinks in the central portion as the grain ripens, while the denser endosperm holds the sides in a straight line. The relative position and amounts of the soft and dense endosperm cause differences in the character and extent of indentation, varying from a ragged dent or projecting flap to a mere dimple or circular depression. Occasionally the grains toward the tip of the ear do not indent, although retaining their dent structure.







Dent maize: ear one-third natural size; grain about natural size.

While there is a wide variation due to climate, season, soil and variety (210), the plant usually varies in height from eight to twelve feet, generally bears but one ear and is not given to suckering unless thinly planted. This type is characterized for its deep grains, rather large diameter of ears and large number of rows, as high as forty-eight rows having been reported for individual ears. Variety differences range from eight to twenty-four rows, sixteen to twenty being the most common. Ears vary in length from five to thirteen inches, and in diameter from one and one-half to two and one-half inches. A good sized ear is eight to nine inches long and from six and one-half to seven inches in circumference at two-fifths its length from the butt. Ten inches is rather long for a dent ear, while seven inches is a good length for smaller

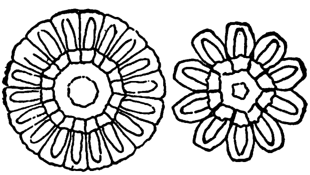
varieties. It is a good ear that weighs three-fourths of a pound. It takes about 100 good ears to make a bushel of shelled maize. One hundred ears of early maturing dent maize will weigh about fifty pounds; of medium maturing, sixty-five pounds; and of late maturing, eighty pounds. One hundred selected ears will weigh sixty, seventy-five and ninety pounds respectively.

Usually the grains are wedge-shaped and deeper than broad. A typical dent grain is five-eighths of an inch deep by three eighths broad and one-sixth of an inch thick. The most common colors are yellow and white, although red grains or those striped with red or similar colors occur in some varieties. Sports of this sort are not uncommon in yellow and white varieties and in some instances this character has been fixed by selection. There is considerable variation in weight of grain: a range of thirty-five to forty-five grams per 100 grains, or from 1,000 to 1,300 grains per pound, is common.

The season ranges from ninety to 150 or even 160 days. There is a wide variation in the same variety in different latitudes and different seasons in the same latitude. In the maize belt States early varieties usually mature from 100 to 115 days, medium varieties from 110 to 135 days and late varieties from 130 to 145 days in ordinary seasons. Dent and flint types furnish all the commercial grain of maize, as well as practically all of the maize fodder and maize ensilage. Only a small fraction of the total is furnished by the flint type.

243. **Description of a Good Dent Ear.**—While variety differences are permissible, there are certain characteristics that are more or less desirable in all varieties. It should be borne in mind that while these ideal characteristics are desirable, other things being equal, their lack of perfection may not prevent a variety from producing high yields or having in other particulars desirable qualities. Cows without horns are desirable, but this does not prevent cows with horns being good milkers. The ear should taper uniformly from butt to tip and should be as near

as possible cylindrical. Such an ear holds the largest amount of grain and contains the largest percentage of grain in proportion to cob, other things equal. Both the butt and tip should be well filled for same reasons and because this indicates full development and maturity as well as adaptation to soil, latitude or season. (217) Excessive length is not desirable when obtained at the expense of poorly filled butt and tip. A good proportion between circumference and length is three to four, or a circumference of six inches for an ear eight inches long. A good size for the circumference of the cob is from three and two-thirds to four and one-third inches. The cob should be neither too large nor too small. It is evident that of two ears of equal size and compactness, the one with the small cob will contain the more grain. On the other hand, while small cobs usually contain the larger proportion of grain, the total weight of the ear is often much less and the yield smaller. A large cob that is not obtained at the expense of the depth of the grain will contain the largest amount of grain. Excessively large cobs, however, are objectionable, as they usually carry large percentages of water, thus lowering the keeping quality of the grain and its vitality for seed. This is likely to be true of ears with enlarged butt and ears that are distinctly tapering, as well as making them more difficult to husk on account of the size of the juncture with the shank. In a good ear the shelled maize will occupy the same space as the ear before it was shelled. It is a good relationship where the depth of grain is one-half the diameter of the cob or the circumference of the ear twice the circumference of the cob. The legal standard in most States is seventy pounds of ears and fifty-six pounds of grain per bushel, or a ratio of cob to grain of one to four or a trifle more. Variations



Space between rows well filled and not well filled.

of fifty-three to sixty-three pounds of grain for seventy pounds of air-dried ears have been noted.[1]

Shamel states that grains with thin tips have low vitality and are low in per cent of fat and protein and high in starch.[2] While it is evident that, other things equal, wide sulci or space between rows will reduce the percentage of grain to cob, it happens that some varieties, as, for example, Hickory King, with large space between rows, have relatively small cobs; hence large percentage of grain although small weight per ear. The roughness of the ear is dependent upon the character of the indentation of the grain. Grains which cause rough ears are usually longer but somewhat less compact than those causing smooth ears. While a smooth ear is pleasanter to husk, there are some excellent varieties whose ears are rough. Aside from its influence upon husking, its importance would seem to be due to the cause which produced it. If a rough ear was caused by lack of proper development and resulted in chaffy, loose grains, it is to be looked upon as undesirable.

244. **List of Varieties of Dent Maize.**—Four white and three yellow varieties have been recognized as distinct varieties by the Illinois Corn Breeders' Association, as follows: (White) Boone County White, Silver Mine, White Superior; (Yellow) Leaming, Reid's Yellow Dent, Riley's Favorite and Golden Eagle.

Following is a list of varieties of dent maize recommended principally for grain production by the stations indicated, including, where possible, the color of the grain of each and the number of years tested:

1 Miss. Bul. 33, p. 76.

2 Manual of Corn Judging, p. 63.

Table containing varieties of dent maize recommended by various stations. (Rated on the basis of grain production, except as otherwise indicated.)

| Station | Authority (Bulletin) | Variety | Color | No. Years Tested |
|---|---|---|---|---|
| Alabama | | | | |
| (Canebrake) | 10 | Madison County Red | Y | 2 |
| (Auburn) | 111 | Mosby | W | 5 |
| | | St. Charles | W | 5 |
| | | Expt. Station Yellow | Y | 5 |
| | | Blount | W | 5 |
| | | Hickory King | W | 5 |
| Arkansas | 59 | Golden Beauty | Y | 2 |
| | | White Dent | W | 2 |
| | | Early Mastodon | Y | 2 |
| | | Champion White Pearl | W | 2 |
| | | Hickory King | W | 2 |
| | | Golden Dent | Y | 2 |
| | | Leaming | Y | 2 |
| Canada | | | | |
| O. A. C. & E. F. | Rpt. 1902 | North Star Yellow Dent | Y | 3 |
| Colorado | Rpt. 1889 | Adams Early | W | |
| Georgia | 62 | Marlboro Prolific | W | 1 to 11 |
| | | Henry Grady | | |
| | | Sander's Improved | Y | |
| | | Eureka | | |
| | | Weekley's Improved | Y | |
| | | Cocke's Prolific | W | |
| | | Bradberry's Improved | Y | |
| | | Moyer's Improved | Y | |
| | | Stone's White | W | |
| | | Fitzpatrick's Improved | Y | |
| | | Shaw's Yellow | Y | |
| | | Shaw White | W | |
| | | Smith's Improved | Y | |
| | | Snowflake | | |
| | | Improved Golden Dent | Y | |
| | | Stone's Yellow Shoe Pad | Y | |
| Illinois | 42 | Boone County White | W | 6 |
| | | Champion White Pearl | W | 6 |
| | | Burr's White | W | 6 |

**Varieties of Dent Maize.—Continued.**

| Station | Authority (Bulletin) | Variety | Color | No. Years Tested |
|---|---|---|---|---|
| Illinois —Continued | 42 | Leaming | Y | 6 |
| | | Clark's Iroquois | Y | 6 |
| | | Legal Tender | Y | 6 |
| | | Murdock | Y | 6 |
| | | Edmonds | Y | 6 |
| | | Riley's Favorite | Y | 6 |
| | | Golden Beauty | Y | 6 |
| Indiana | 55 | Purdue Yellow Dent | Y | 5 |
| | | Hartman's White | W | 5 |
| | | Fleming's Yellow | Y | 5 |
| | | Boone County White | W | 5 |
| | | Yellow Speckled Dent | Y | 5 |
| | | Early Yellow | Y | 5 |
| | | Riley's Favorite | Y | 5 |
| Iowa | 55 | Reid Yellow Dent | Y | 3 |
| | | Legal Tender | Y | 3 |
| | | Snow Flake White | W | 3 |
| | | Seckler Perfection | | 3 |
| | | Champion White Pearl | W | 3 |
| | | Golden Beauty | Y | 3 |
| | | Mammoth Cuban | | 3 |
| | | Western Yellow Dent | Y | 3 |
| | | Nebraska White Prize | W | 3 |
| | | Lenocher Homestead | | 3 |
| Kansas | 64 | Early Thompson | Y | 3 |
| | | Hartman | W | 3 |
| | | Early White | W | 3 |
| | | Pride of Kansas | | 3 |
| | | Boone County White | W | 3 |
| | | Early Yellow Rose | | |
| | | Champion Yellow Dent | Y | 3 |
| | | Basis of Grain and Stover: | | |
| Louisiana | 71 | Virginia White Dent | W | 1 |
| | | Gandy | | 1 |
| | | Champion Yellow Dent | Y | 1 |
| | | Red Driver | | 1 |
| | | Yellow Creole | | 1 |

## Varieties of Dent Maize.—Continued.

| Station | Authority (Bulletin) | Variety | Color | No. Years Tested |
|---|---|---|---|---|
| Louisiana —Continued | | Marlboro's Prolific | W | 1 |
| | | Clark's Early Mastodon | Y | 1 |
| Massachusetts (Hatch) | Rpt. 1902 | Ensilage Vars: | | |
| | | Rural Thoroughbred | | |
| | | Leaming Field | Y | |
| | | Eureka | | |
| | | Boston Market (sweet) | W | |
| Mississippi | 79 | Mosby Prolific | W | |
| | | Tatum Choice | | |
| Missouri | 32 | Golden Beauty | Y | 3 |
| | | Leaming | Y | 3 |
| | | Piasa King | W | 2 |
| | | St. Charles White | W | 2 |
| Nebraska | 83 | Hogue's Yellow Dent | Y | 2 |
| | | Reid's Yellow Dent | Y | 2 |
| | | Legal Tender | Y | 2 |
| | | Golden Row | Y | 2 |
| | | Golden Cap | Y | 2 |
| | | Snowflake White | W | 2 |
| | | Early Yellow Rose | Y | 2 |
| | | Nebraska White Prize | W | 2 |
| | | Leaming | Y | 2 |
| | | Mammoth Golden Yellow | Y | 2 |
| | | Calico | Mixed | 2 |
| | | Early Cattle King | Y | 2 |
| | | Iowa Gold Mine | Y | 2 |
| | | Boone County White | W | 2 |
| | | Mammoth White Pearl | W | 2 |
| | | Silver Mine | W | 2 |
| | | Riley's Favorite | Y | 2 |
| | | Pride of the North | Y | 2 |
| | | Minnesota No. 13 | | |
| Nevada | Rpt. 1891 | Pride of the North | Y | 1 |
| | | Stover: | | |
| | | Piasa Queen | W | 1 |
| New Hampshire | 92 | Leaming | Y | |

**Varieties of Dent Maize.—Continued.**

| Station | Authority (Bulletin) | Variety | Color | No. Years Tested |
|---|---|---|---|---|
| | | Ensilage Varieties: | | |
| New York | Rpt. 1889 | Hickory King | W | |
| | | Blount's Prolific | W | |
| | | Burrill & Whitman | W | |
| | | Cleveland's Colossal | | |
| | | Piasa Queen | Y | 1 |
| | | Grain and Stover: | | |
| North Carolina | 171 | 100-Day Bristol | W | |
| | | Delaware Co. Dent | | |
| | | Johnson & Stokes' Giant Beauty | | |
| | | Leaming | Y | |
| | | Golden Beauty | Y | |
| | | Grain and Silage: | | |
| | | Cocke's Prolific | W | |
| | | Northern White Field | W | |
| | | Blount's Prolific | W | |
| | | White Dent | W | |
| | | Red Cob Ensilage | W | |
| North Dakota | Rpt. 1902 | Northwestern Dent No. 124 | Y | |
| | | Early Ripe Fodder No. 152 | | |
| Ohio | 140 | Missouri Leaming | Y | 1 |
| | | Reid's Yellow Dent | Y | 2 |
| | | Henderson's Eureka | Y | 3 |
| | | Farmer's Favorite | Y | 3 |
| | | Darke Co. Early Mammoth | Y | 6 |
| | | Leaming | Y | 4 |
| | | Medium Maturing Varieties: | | |
| | | Clarage | Y | 10 |
| | | Leaming Cuppy | Y | 5 |
| | | White Cap Yellow Dent | W & Y | 7 |
| | | Early Maturing Varieties: | | |
| | | Pride of the North | Y | 8 |
| | | King of the Earliest | Y | 9 |
| | | Early Butler | Y | 10 |
| | | Extra Early Huron Dent | Y | 9 |

**Varieties of Dent Maize.—Continued.**

| Station | Authority (Bulletin) | Variety | Color | No. Years Tested |
|---|---|---|---|---|
| | | For Grain and Silage: | | |
| Oregon | 35 | Pride of the North | Y | |
| | | Minnesota King | Y | |
| | | Huron Pure Yellow Dent | Y | |
| | | Forsyth's | W | |
| | | On Bottom Land: | | |
| South Carolina | 61 | Boggs' Home-grown | | |
| | | Albemarle Prolific | W | |
| | | Whitmire's Mt. Seed Corn | | |
| | | Garrick's | | |
| | | On Thin Upland: | | |
| | | Albemarle Prolific | W | |
| | | Garrick's Improved | | |
| | | J. E. Lewis' Prolific | W | |
| | | Sander's Improved | Y | |
| | | Boggs' Home-grown | | |
| | | Mosby's Prolific | W | |
| South Dakota | 24 | Loveland's Dent | R | |
| | | Hughson's Dent | Y | |
| | | Pride of the North | Y | |
| | | Minnesota King | Y | |
| Tennessee | XIV, No. 1 | No. 3,889 | | 1 |
| | | Improved Golden Beauty | Y | |
| | | Improved Leaming | Y | |
| | | Varieties for Fodder: | | |
| | | Florida | | |
| | | No. 3,889 | | |
| | | Ellis | | 1 |
| | | Huffman | W | |
| Texas | 49 | Blount's Prolific | W | 3 |
| | | Murdock | Y | 3 |
| | | Golden Beauty | Y | 3 |
| | | Forsyth's Favorite | W | 2 |
| | | Hickory King | W | 3 |
| | | Leaming | Y | 3 |
| | | Early Mastodon | Y | 3 |
| | | Southern White Gourd Seed | W | 3 |
| | | Riley's Favorite | Y | 3 |

## Varieties of Dent Maize.—Continued.

| Station | Authority (Bulletin) | Variety | Color | No. Years Tested |
|---|---|---|---|---|
| Utah | 66 | Salzer's Earliest Canadian Yellow | Y | 5 |
| | | Wisconsin Early White | W | 8 |
| | | Long Yellow Dent | Y | 5 |
| | | Queen of the North | Y | 7 |
| | | Clark's Early Mastodon | Y | 9 |
| | | King of the Earliest | Y | 10 |
| | | Early Huron Dent | Y | 7 |
| | | Queen of the Field | Y | 10 |
| | | Champion White Pearl | W | 10 |
| | | Hickory King | W | 9 |
| | | Ensilage Varieties: | | |
| Vermont | Rpt. 1890 | Burrill & Whitman | W | |
| | | Capital | Y | |
| | | Champion Pearl | W | |
| | | Early Prolific | W | |
| | | Early Mastodon | Y | |
| | | Evans | Y | |
| | | Hickory King | W | |
| | | Prairie Queen | Y | |
| | | Virginia Horsetooth | W | |
| Wisconsin | 19 | Southern Horsetooth | | |
| | | Southern Ensilage | | |
| | | Smedley Dent | Y | |
| | | Normandy White Giant | | |
| | | Fargo Bros. Ensilage | | |
| | | Burrill & Whitman Ensilage | W | |
| | | Sibley's Sheep Tooth | | |
| | | Evergreen (sweet) | | |
| Wyoming | 22 | Minnesota King | Y | |
| | | Dakota Dent | Y | |

**245. Classification of Dent Varieties.**—Dent varieties may be classified into eighteen groups as follows:

| | | | |
|---|---|---|---|
| Early maturing | Grains white | Ears smooth | 1 |
| | | Ears rough | 2 |
| | Grains yellow | Ears smooth | 3 |
| | | Ears rough | 4 |
| | Grains other colors | Ears smooth | 5 |
| | | Ears rough | 6 |
| Medium maturing | Grains white | Ears smooth | 7 |
| | | Ears rough | 8 |
| | Grains yellow | Ears smooth | 9 |
| | | Ears rough | 10 |
| | Grains other colors | Ears smooth | 11 |
| | | Ears rough | 12 |
| Late maturing | Grains white | Ears smooth | 13 |
| | | Ears rough | 14 |
| | Grains yellow | Ears smooth | 15 |
| | | Ears rough | 16 |
| | Grains other colors | Ears smooth | 17 |
| | | Ears rough | 18 |

Classification based upon maturity is open to the objection that the maturity is affected by season and climate, that what is an early variety in one locality may become a late variety in another, and *vice versa*. A classification based upon roughness of ear is difficult because of the almost insensible gradation from extreme smoothness to extreme roughness.

A classification based upon specimen ears alone may be as

follows: grains broader than deep, as deep as broad, and deeper than broad. It may be further subdivided according to evenness of ear: shallow rounding, moderately rounding, or deeply rounding at butt; and still further subdivided in accordance with the shape of ear, number of rows per ear, and color of grains.

246. **Soft Maize** is that type in which the endosperm is white, the corneous endosperm being entirely absent. The shape and outward appearance of the grain is similar to that of the flint type, but varies in size from not much larger than grains of pop maize to the largest known. The variety Cuzco from Peru has grains fifteen-sixteenths inch deep by eleven-sixteenths inch broad. The color is quite variable. The ears resemble those of the flint type, but are usually shorter, with slightly larger diameter.

This type is widely distributed and apparently was largely grown by the Indians on account of the ease with which it could be crushed. It is not grown for commercial purposes in North America. It is said that in some instances it is grown in place of sweet maize for eating green along the western coast of South America. Most of the varieties experimented with in the United States have either not matured or else have been very late in maturing.

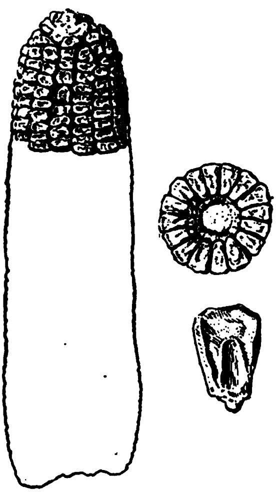
247. **Sweet Maize** is that type in which the endosperm is translucent and horny in appearance, the starch having been more or less reduced to sugar.

What is probably a variation from this type is described by Sturtevant as starchy-sweet corn (*Zea amyleasaccharata* Sturt.). In this type the lower half of the grain is starchy, the upper half horny and translucent; otherwise it is like the ordinary sweet type. Varieties of this type were found in the San Pedro Indian collection, but failed to mature at Geneva, N. Y.[1]

The grains of sweet maize are usually broadly wedge-shaped, with more or less rounded summit and a characteristically wrinkled surface. While varying largely, a typical grain is one-

[1] Bul. Torr. Bot. Club, Vol. XXI, No. 8, p. 334.

half inch deep, three-eighths inch wide by one-eighth inch thick. One hundred grains commonly weigh from twenty to twenty-seven grams, or from 1,700 to 2,800 grains per pound. The plant is reported to vary in height from two to ten feet; usually from five to eight feet, and not infrequently bears more than one ear. There is considerable tendency to sucker. The ears vary in length from four to eleven inches; usually from six to eight inches, and in diameter from one and one-fourth to two and one-fourth inches; usually from one and one-half to one and three-fourths inches. The rows vary from eight to twenty-four, the greater number of varieties being twelve-rowed. Stowell Evergreen, the variety most extensively grown for canning purposes, is somewhat larger: ear seven to nine and one-half inches long, diameter two and one-fourth inches; twelve to twenty-rowed.



Sweet maize: variety, Stowell Evergreen. Ear and cross section one-third natural size; grain natural size.

The weight of ear varies largely with variety, those of early varieties being much smaller than late varieties. Selected ears have been found to vary from seven and a half pounds to seventy-five pounds per hundred, the most common weight being from twenty-five to forty pounds per hundred for selected ears.

The time required to bring sweet maize into edible condition varies with variety, climate and season from fifty-four to 115 days; usually from sixty to ninety days. From the earliest to the latest varieties there is a difference in any one season of from three to four weeks. Sweet maize is extensively raised for cooking and eating while in the milk stage. It forms the basis

of a large canning industry in the North Atlantic and North Central States. It is less generally grown in the Southern States. It is believed to improve in quality as it proceeds northward, Maine grown sweet maize being especially prized.

"The first sweet corn recorded in American cultivation was the Papoon corn, an eight-rowed variety with red cob, introduced into the region about Plymouth, Mass., from the Indians of the Susquehanna in 1779."[1]

Eleven stations have recommended lists of varieties of sweet maize. The following list has been recommended by three or more stations: Early: Cory, Marblehead, Crosby, Chicago Market, Early Landreth; Medium: Squantum, Maule's XX, Stabler's Early; Late: Ne Plus Ultra, Stowell Evergreen, Country Gentleman.

**248. Number of Varieties.**—The distinct names given to varieties of maize are almost innumerable, and no complete study of them has ever been made. Sturtevant[2] describes 507 varieties and 266 synonyms classified by types as follows:

| Type | Number of varieties | Number of synonyms |
|---|---|---|
| Pop | 25 | 18 |
| Flint | 69 | 85 |
| Dent | 323 | 109 |
| Soft | 27 | 1 |
| Sweet | 63 | 53 |

It is stated that some of the varieties would upon further study be found to be synonyms of other varieties.

**249. Varieties for Silage.**—The dent type is used almost exclusively for silage on account of its greater total yield of forage. Experiments made at the Maine Station,[3] where dent varieties have the least adaptation of any State for ordinary field pur-

[1] U. S. Dept. of Agr., O. E. S. Bul. 57, p. 18.

[2] Varieties of Corn. U. S. Dept. of Agr.. O. E. S. Bul. 57.

[3] Me. Rpt. 1891, p. 44.

pose, show the following results for three years 1889 to 1891 inclusive:

| Type | Variety | Total crop as harvested per acre | Yield of dry matter per acre |
|---|---|---|---|
| Dent | White Horse-tooth[1] | 35,195 | 4,798 |
| Flint | Local | 19,197 | 2,893 |
| Sweet | Early Crosby | 16,908 | 2,420 |

During five years the average yield of dry matter has been for the dent variety 5,036 pounds and for the flint variety 4,224 pounds. The Pennsylvania Station[2] found that the dent fodder yielded forty-five per cent more dry matter than flint fodder. The flint variety contained a considerably larger percentage of protein and smaller percentage of crude fiber. At Cornell Station[3] Sibley's Pride of the North yielded ten per cent more dry matter than an eight-rowed flint. Ontario Agricultural College compared the feeding value of dent maize and sweet maize silage and found the latter slightly superior in feeding value—believed to be due to greater palatability in this case—but the increased yield of dent maize more than compensated for the decrease in feeding value.[4]

Varieties originating in the South Atlantic and South Central States are frequently sold in the North Atlantic and North Central States as silage maize. The season of growth being longer than northern grown varieties, they continue to grow later in the season, thus often producing a greater yield of silage per acre than those varieties grown principally for their grain. These so-called silage varieties do not produce as large a proportion of ears to stalk and leaves, and in many cases the per cent of water is higher, thus requiring the handling and storing of more tons of silage for an equal amount of dry matter and of food value. When silage is put up too green its keeping quality and

[1] Southern variety.

[2] Penn. Rpt. 1891, p. 30.

[3] Cornell Bul. 4, p. 51.

[4] Ont. Agr. Col. and Expt. Farms Rpt. 1897, p. 83.

food value are lessened. (353) For silage, it is generally desirable to plant a variety which will develop a normal proportion of ears and that will get as mature as it is possible for maize to be when put in the silo. (349)

250. **Comparative Yield of Dent and Flint Maize.**—Almost all of the field maize of the United States, comparatively speaking, is of the dent type. Flint maize requires a smaller number of days to mature a crop; hence it is used in the more northern latitudes and at higher altitudes. It is the common field crop of New England. Each of these types has its place, but wherever the common varieties of dent maize will ripen flint maize usually is not desirable. For example, at the Pennsylvania Station eleven varieties of flint maize and fifteen varieties of dent maize have been tested from one to three years. The altitude is 1,200 feet; the season, therefore, is comparatively cool and short, and not especially adapted to the growth of dent varieties. The following table gives the yield of dry matter in pounds from ears and stover:

| | Flint | Dent |
|---|---|---|
| Ears . . . | 1,750 | 3,012 |
| Stover . . . | 1,691 | 3,258 |
| Total . . | 3,441 | 6,270 |

# XI.

## MAIZE.

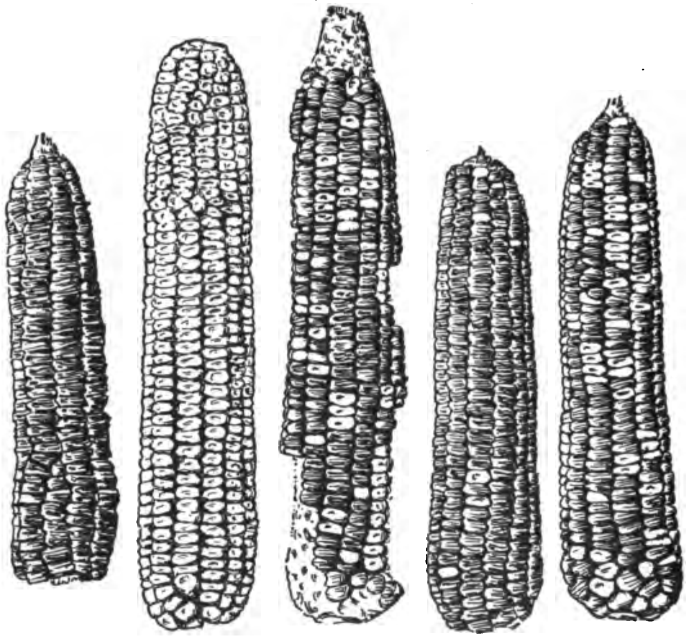
### IMPROVEMENT OF VARIETIES.

251. **Pollination.**—Maize is said to be wind-fertilized, since the extremely abundant pollen is carried long distances by the wind and often deposited upon silks of ears quite remote from the tassel bearing the pollen. Notwithstanding the large amount of observation and experiment, the extent to which maize is cross-fertilized and to what extent it is self-fertilized in actual practice has not been clearly established. It is believed by many, however, that since the pollen appears to develop slightly in advance of the silks of the same plant, and since the tendency of the currents of air would be to carry the pollen away from the plant producing it, that cross-fertilization is the rule and self-fertilization the exception. It has been clearly established, however, that both cross-fertilization and self-fertilization can readily be effected. Artificial or hand pollination usually does not produce as good results as when pollination takes place in the natural way.

The ovules are fertilized in order of sequence from butt to tip. Since the tip grains develop last, the tip of the ear is the most variable, due to variations in soil, cultural or seasonal conditions. It is probable that the filling out at the tip of the ear should be looked upon as the result of environment more than as an hereditary or variety characteristic. (243)

252. **Influence of Current Cross.**—The influence of pollen upon the grain or fruit which immediately develops, called *xenia*, has received considerable study especially in maize. That the character of the male pollen may affect the endosperm of the

fertilized ovule is certain. When sweet maize is crossed with dent pollen, the resulting grains have the appearance of flint grains, being neither dented nor wrinkled, and have the taste of dent maize. Sweet maize shows the influence of the current



1 2 3 4 5

Black Mexican sweet-white dent cross. Ear 1 is Black Mexican sweet maize which was used as the male parent. Ear 2 is a white dent variety used as the female parent. Ear 3 shows the intermediate result of the cross, grains from which were planted to produce ears 4 and 5. Ear 4 was from the wrinkled or sweet grain of ear 3. Ear 5 was grown from the dent grains of ear 3 (after McCluer).

cross when pollinated by dent maize with such certainty that grains which do not show the effect may be depended upon to produce a pure product the next year.[1] When sweet maize is

[1] R. I. Rpt. 1901, pp. 227-244.

the male and dent maize the female parent, McCluer[1] has shown both sweet and dent grain in the current cross, and that the dent grain when grown would show sweet characters. There is a strong tendency for color, where it is a character of the endosperm, to show in the current cross.

Webber has shown that the aleurone layer may be affected by the current cross. Cuzco, a soft variety, with heliotrope-purple color in the aleurone layer, was crossed upon several varieties of dent maize, and grain resulting from such fertilization contained the same or similar color in the aleurone layer.[2] The immediate effect of pollen upon the color when the color is in the seed coat, as in calico maize, is denied by some, and the observed instances have been explained by assuming that the seed of the female parent was impure.

253. **Degree of Close Breeding.**—There may be several degrees of closeness in breeding maize: (1) Between pollen and ovules of the same plant; (2) between pollen and ovules of plants grown from seed from the same ear; (3) between pollen and ovules of plants grown from seed from different plants of the same variety. The closeness of relationship of the plants furnishing the seed may vary between very wide limits. They may have had a common ancestor but one generation back, or they may have been unrelated in one or both ancestors for many generations; (4) between pollen and ovules of plants grown from seed of different varieties; (5) between pollen and ovules of plants grown from seed of different types.

254. **Close Breeding.**—Since cross-fertilization appears to be the rule in maize, it is generally considered desirable to avoid any practice which would induce close-fertilization. (106) Hopkins states that he has secured data pointing toward an injurious effect of close-pollination and recommends cross-pollination in

[1] Ill. Bul. 21, p. 87.

[2] Xenia, or the immediate effect of pollen in maize. U. S. Dept. of Agr., Div. Veg. Phys. and Path. (1900) Bul. 22.

seed maize breeding by detasseling alternate rows.[1] Webber reports several instances of the injurious effect of inbreeding maize with pollen from the same plant, of which the following is an example: One hundred stalks of Hickory King grown from seed inbred with pollen from the same stalk yielded forty-six ears weighing nine and three-tenths pounds, while seed of the same race produced by crossing different seedlings yielded from the same number of stalks eighty-two ears weighing twenty-seven and a half pounds. In another instance hybrids of the second generation, where seed was inbred, showed great loss of vigor, being small in structure and almost sterile.[2] McCluer[3] found that plants grown from self-fertilized seed, besides producing smaller ears, produced a greater proportion of barren stalks and were subject to numerous deformities.

255. **Detasseling.**—Detasseling alternate rows of maize has been tried as a means of increasing the yield of grain, on the theory that plant food that goes to maturing the tassel and the production of pollen may be diverted to the grain. Ten stations have published results as shown in table on opposite page.[4]

In one instance the Cornell Station found an increase of fifty per cent in the detasseled rows, but ordinarily the increases and decreases found have fallen within twenty per cent. It should be noted that these percentages apply to only half the field. While the evidence is not entirely clear, the inference of experiments so far reported seems to be that increase from detasseling is most likely to occur on poor soil or in dry seasons. In discussing these results the Cornell Station says:

"The tassels were removed by hand by pulling them out as soon as they appeared. This operation was performed quite rapidly as comparatively little force was necessary to cause the stalk to break just above the upper joint and without

1 Ill. Bul. 82 (1902), pp. 535-536.

2 Science, N. S., Vol. XIII, No. 320 (1901), pp. 257-258.

3 Ill. Bul. 21, p. 96.

4 Ohio Rpt. 1897, p. 64.

any injury to the leaves whatever, if done before the tassels had become fully expanded. From the experiments in detasseling made at the station it is thought to be of prime importance to completely remove the tassel before it has expanded and commenced to shed pollen. As the tassel at this time is partially protected within the folds of the leaves, it can only be completely removed by grasping the top of the tassel and giving it an upward pull which causes it to break off as described above. Experiments in detasseling have been made at other experiment stations where the practice has been to remove the tassels by cutting them off with a corn knife which would either cause an injury to the leaves or a delay until the tassels had become fully expanded and had shed pollen, as some tassels will shed pollen while yet partially protected within the folds of the leaves. In either case a benefit ought not to be expected from the practice. Our experiments show that the object of removing the tassels is not accomplished if they are allowed to remain until fully expanded and become polleniferous."[1]

**Summary of Results Obtained in Detasseling Maize.**

| Station | Total number of tests | Effect | | |
|---|---|---|---|---|
| | | Crop increased | No effect | Crop decreased |
| Cornell University | 4 | 3 | 1 | .. |
| Delaware | 2 | 2 | .. | .. |
| Georgia | 1 | .. | 1 | .. |
| Illinois | 3 | 1 | 1 | 1 |
| Kansas | 3 | 1 | 1 | 1 |
| Maryland | 1 | .. | .. | 1 |
| Nebraska | 2 | .. | .. | 2 |
| Ohio | 2 | .. | 1 | 1 |
| South Carolina | 1 | 1 | .. | .. |
| Utah | 2 | .. | .. | 2 |
| Totals | 21 | 8 | 5 | 8 |

In one trial the Illinois Station[2] found an increase of twenty-seven per cent when tassels were pulled out and six per cent when cut out;—an increase of fifteen per cent when removed before tassels were expanded and eleven per cent when removed after tassels were expanded.

[1] Cornell Bul. 61 (1893), p. 312.

[2] Ill. Bul. 37, p. 22.

256. **Crossing.**—What influence the crossing which the detasseling of alternate rows of maize compels has upon the subsequent progeny is not shown in the experiments just related, since to determine this it is necessary to grow the seeds thus crossed.

The Illinois Station[1] crossed a number of varieties in 1892, grew the cross-bred varieties in 1893 and again in 1894, comparing the yield with the average yield of the two parent varieties. In 1894, in four out of six cases, the yield was greatest for the cross, the average increase being twelve bushels per acre. In 1893 three out of four gave the largest yields for the cross, the average increase being two and three-tenths bushels per acre; and in 1892 five crosses gave in every case a larger yield than an average of the parent varieties, the average increase being nine and a half bushels per acre. The conditions under which it was necessary to conduct these experiments made the results inconclusive.

When McCluer[2] raised crosses from different types of maize, the progeny from the full cross was in nearly all cases increased in size as a result of the crossing. In nearly all cases this increase in size was not marked the second year, although yet larger than the average of the parent varieties. This may have been due to a tendency to revert to the character of the original ancestor or may have been due to each plat being grown from a single ear, thus bringing about at once inbreeding.

257. **Disposition to Maintain Types and Varieties.**—When sweet maize is crossed with a dent variety the grains of the current cross on the ear may all assume a smooth rounded appearance not unlike a flint variety. The plants that grow from these grains will produce ears which will have some grains of the dent type and some of the sweet type, thus showing a tendency to split up into the separate types and to prevent the production of an intermediate type. The same tendency is somewhat apparent, although less noticeable, in crosses between varieties of the same type. While the readiness with which maize cross-fertilizes tends to obliterate varieties, this tendency opposes it. (278)

[1] Ill. Bul. 37, p. 20.
[2] Ill. Bul. 21, pp. 95-96.

**258. Breeding for Composition.**—Hopkins found that when analyses were made of different samples coming from a considerable number of ears that the composition of the grain was quite uniform. When, however, samples were taken separately, even from different ears of the same variety, there were considerable differences in the composition. Some variation was found in the composition of grains from the butt, middle and tip third of the ear, but when one or more rows were taken throughout the whole length of the ear the composition of this sample was found quite accurately to represent the whole ear. He further established the fact that if the grains of ears varying in composition were grown separately, this difference in composition would be found in the resulting crop. It was thus established that composition was hereditary. He also showed that the composition would be determined in considerable measure by the physical distribution of the parts of the grain.

**259. Breeding for Fat.**—As thirty-five per cent of the embryo is fat and as eighty to eighty-five per cent of all the fat of the grain is in the embryo, it is evident that grain with large embryos would contain larger percentages of fat than those containing small embryos, unless the per cent of fat in the embryo itself varied largely.[1]

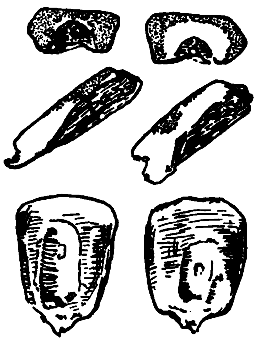
Beginning with the same variety of maize, ears were selected four years for high fat and low fat content. Then rows were planted with both kinds of maize, every hill having each kind of maize just far enough apart to identify the stalks. Thus they were grown in the same season, in the same soil and under the same cultivation. The resulting crop from maize selected for low fat content contained three and eight-tenths per cent of fat; that for high fat, five and eight-tenths per cent of fat.[2] In other instances there have been brought about

[1] The investigations of Hopkins appear to show that large embryos contain a larger percentage of fat than small embryos. Ill. Bul. 87, p. 105.

[2] Ill. Bul. 87, p. 100.

variations in content of fat ranging from two and a half to seven per cent.

260. **Breeding for Protein.**—The relative proportion of glossy and white endosperm varies largely in the grains of different ears of the same variety of maize. In an average ear of Burr's white (dent variety) ten and two-tenths per cent of protein was found in the glossy endosperm and seven and eight-tenths per cent in the white endosperm. (226) Hopkins finds forty-two per cent of all the protein of the grain in the endosperm, and, also, holds that the aleurone layer, which also has a high per cent of protein, is larger in maize selected for high protein content. As the ratio of glossy to white endosperm is readily estimated by making selections of a few grains from each ear, assuming the above propositions established, maize may be bred for high or for low protein content. By this method, maize has been bred which contains but six and seven-tenths per cent of protein and as high as fourteen and four-tenths per cent.



The grains on the left contain the higher percentage of protein indicated by the higher proportion of glossy or corneous endosperm as compared with the white or soft endosperm, and, also, possibly, by the larger embryo. (After Hopkins.)

Since the embryos contain a higher per cent of protein than the glossy endosperm and about the same percentage as the aleurone layer, it has been suggested that the variations in the per cent of protein were largely due to variations in the size of the embryos. Hopkins, however, has gone into a rather elaborate investigation to show that variations in the percentage of protein are due primarily to variations in the glossy endosperm and the aleurone layer and only secondarily to the variations in the embryo.[1]

261. **Breeding for Starch.**—In order to breed for high starch content, we have only to breed for low protein and low oil content, as, practically speaking, the percentage of carbohydrates (principally

1 Ill. Bul, 87, pp. 96-101.

starch) is usually inversely proportional to that of the protein and fat. If maize were bred for the manufacture of starch or glucose, only low protein content would be desired, since the fat or maize oil, which is a by-product of the manufacture of starch, is worth more per pound than the starch.

262. **Advantage of Breeding for Composition.**—Throughout the North Central and Eastern States, and especially in those States which raise a great surplus of maize, stock foods generally contain too small a proportion of digestible protein. The protein is, therefore, the most expensive ingredient of stock foods, being several times more expensive per pound than maize itself. The raising of maize with a higher percentage of protein would reduce the need of purchasing more expensive nitrogenous foods, and would thus cheapen the food supply, provided the yield of maize is not reduced as the per cent of protein is increased. In the Southern States, the food supply for live stock is highly nitrogenous, due to large surplus of cotton seed, cottonseed meal and cowpeas. In this section, a high starch content may be desirable. Large quantities of maize are annually used for the manufacture of starch and glucose. The Glucose Sugar Refining Company[1] says:

"A bushel of ordinary corn, weighing 56 pounds, contains about 4 1-2 pounds of germ, 36 pounds of dry starch, 7 pounds of gluten and 5 pounds of bran or hull, the balance in weight being made up of water, soluble matter, etc. The value of the germ lies in the fact that it contains over 40 per cent of corn oil, worth, say, 5 cents per pound, while the starch is worth 1 1-2 cents, the gluten 1 cent and the hull about 1-2 cent per pound.

"It can readily be seen that a variety of corn containing, say, one pound more oil per bushel would be in large demand."

263. **Disadvantage of Breeding for Composition.**—One disadvantage of breeding for composition and yield at the same time is that breeding for two characteristics at one time is several times more difficult than breeding for one. An objection to breeding for high protein is that the amount of nitrogen re-

[1] Ill. Bul. 82 (1902), p. 526.

moved from the soil will be increased, unless the yield of maize is decreased. No results have been reported of the influence upon yield of breeding for high protein or other modifications in composition. Whether it is better to raise the surplus nitrogen needed in leguminous crops like clover, alfalfa, soy beans, cowpeas, field peas, etc., and to raise maize primarily as a source of easily digestible carbohydrates, will need to be settled by each grower in accordance with local conditions, assuming that composition has no influence upon yield.

264. **Methods of Breeding.**—Breeding for composition has served to call attention to the method of testing hereditary power, whether the character to be tested was high protein, fat or yield.

After several ears of maize have been selected for high protein, it becomes necessary to determine whether they will reproduce ears with high protein, and also to place the plants produced from such selected ears where they will be fertilized by pollen from plants having high protein content. If this is an advantage in the case of ears selected for high protein, it is also an advantage for ears selected for high yield. Large ears may be the result of environment or may be due to hereditary power. Of two ears of equal merit (as, for example, size), one grown on very rich soil and the other on ordinary soil, the latter should be preferred for seed.

265. **The Breeding Plat.**—Assuming total yield of grain to be the character bred for, the following is an outline of plan to be followed in the breeding plat, the details to be modified according to circumstances:

(1) First carefully consider the variety of maize best suited to conditions. Do not waste time improving a poor variety or strain. Having selected the variety, it will generally be wise to grow no other.

(2) Select 100 ears of perfect vitality of this variety. Weigh each ear separately and arrange in order of weight.

(3) From these 100 ears select forty nearest the ideal sought, giving due importance to weight of ear, but not neglecting other qualities.

(4) Next shell each ear separately, weigh cobs and determine total weight and per cent of shelled grain to ear. The total weight of grain is more important than the per cent. There is no necessary relation between per cent of grain to ear and yield. Large cobs may, however, be objectionable for other reasons, as, for example, their influence upon maturity and preservation of the ear. With the information obtained, select twenty-five out of the forty ears and number ears 1 to 25, making the best ear No. 13, the next best ears 12 and 14 and the poorest ears 1 and 25.

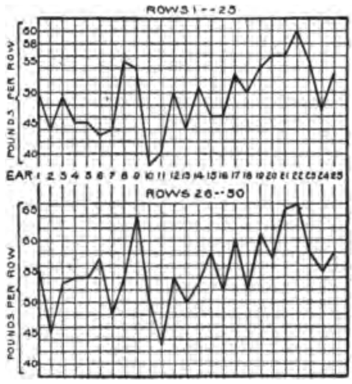



Diagram showing the influence of heredity and environment upon yield of maize. Curves show yield per row in pounds of field cured grain of fifty rows grown from twenty-five different ears of the same variety. Rows No. 1 and No. 26 grown from seed of ear No. 1; rows No. 2 and No. 27 from ear No. 2, etc. The rows were each fifty hills long, and each hill, with very few exceptions, had exactly three stalks per hill. Grown in Fayette county, Ohio, by L. H. Goddard.

(5) Lay off a piece of uniform land fifty hills square and plant rows 1 and 26 to ear 1; rows 2 and 27 to ear 2, until ear 25 is planted on rows 25 and 50. Place five grains in each hill, and when plants are three to four inches high, thin so that each row has 150 plants. If this plat of maize is planted by itself, four rows should be planted clear around the plat from what is left of the twenty-five selected ears. In many cases the most practical way will be to plant the plat in the body of a field containing the ordinary crop, which will be the same variety. The breeding plat should not be within twenty rods of neighboring maize fields, especially if the variety is different.

(6) When properly matured, husk and weigh the ears from each row separately under exactly uniform conditions. If the progeny of a certain ear yields more maize than does either row from another ear, it may be assumed that the former has the superior hereditary force and that the greater yield was not the result of environment, as, for example, better soil.

(7) For next year's breeding plat, select twenty-five ears from the progeny of a few of the best ears, say the best five ears. It would probably not be safe to select all the ears from the progeny of the best ear, as that would lead to very close breeding. It will also be desirable to arrange for as much crossing as possible between ears of unlike parentage. Select the best of what is left from the breeding plat for the field crop. The breeding plat is to be continued indefinitely.

266. **Field Selection.**—The usual method of obtaining seed is to select ears from the regular field crop. There are three methods:

(1) Selection of ears from the crib.

(2) Selection of ears at the time of husking.

(3) Selection of ears by passing through the field before husking and while plants are still standing in the field.

The reason for employing the second method over the first is that the seed may be dried before low temperature has an opportunity to injure or destroy the vitality. The advantage of the third method over the first is that it gives opportunity to observe the character of stalk and leaves when selection is made. The advantage of the second method is that it gives a wider range of selection and makes more certain the finding of the best ears, since every ear is handled.

267. **Field Seed and Breeding Plat Seed Compared.**—The advantage of the breeding plat method of securing seed is that it permits the selection of seed that has shown its ability to produce the highest yield or the highest per cent of protein, as the case may be, under substantially similar environment. Under field selection it is not so certain that size of ear was not the result

of environment, and the ability of a strain to produce occasional large ears is not necessary proof of large average yield. Undoubtedly, however, field selection has great merit, since it enables the selection of the finest ears of the character desired. The disadvantage of the breeding plat is that it limits the range of selection to perhaps an acre of maize, while in field selection twenty, forty or even 100 or more acres may be available from which to make selections. The importance of this wider selection will depend upon the extent to which the finest ears under ordinary field culture are due to the environment and to what extent they are hereditary variations. This has not yet been satisfactorily proven. Another possible disadvantage of the breeding plat is that it leads to close breeding. (254)

**268. Vitality of Seed.**—Owing to the time of maturity, the vitality of seed is often injured by freezing before the grain is thoroughly dry. It is the water that freezes and thereby destroys the tissue. The vitality may be preserved in two ways: first, by thorough drying; second, by not subjecting to a low temperature. If the grain is dried thoroughly, low temperature will not injure it. The first method is usually the most feasible. In southern latitudes this may be accomplished by storing in narrow cribs, but in more northern latitudes hanging in an airy place sufficiently protected from cold to cause thorough drying before severe weather begins, or drying by means of artificial heat, is desirable. The latter method is now being practiced by some who make a specialty of raising seed maize.

Room for drying maize for seed by artificial heat.

**269. Importance of Testing Vitality of Seed.**—It is very important, not only that seed should grow, but that it should grow

vigorously. The vitality may be injured and the seed still sprout. The less the percentage of seed sprouting, the less the vital power. The Illinois Station found in the case of sweet maize that when ninety-five per cent of the seed grew in the greenhouse, but seventy-five per cent of the seed which grew in the greenhouse grew in the field; while where fifty-two per cent grew in the greenhouse test, only fifty-five per cent of those which grew in the greenhouse grew in the field. A perfect stand of vigorous seedlings is an important element in successful culture of maize. (303) The New York State Station[1] reports:

"While in germination, in one trial, the vitality as expressed in per cents was precisely the same as between two lots of 500 seeds each, the one corn from the crib and the other thoroughly dried over a radiator, viz., 94 per cent, yet when the same corn was planted in the earth the difference became very marked, the corn from the crib giving but 20 per cent vegetation and the same corn kiln-dried giving 80 per cent vegetation. The difference was even more marked in the growth, the corn from the crib attaining a height of only three inches, while that from the kiln-dried seed had reached the height of five inches in the same time."

270. **Germination.**—Sturtevant has shown that the different types of maize would germinate at a temperature of 41° to 43.7° F. in from ten to twenty days. When the temperature varied from 48.5° to 58.5° F., from five to nine days were required for germination. At these temperatures sweet maize required somewhat longer time to germinate than the other types.[2] Sachs and Ward give the highest temperature at which maize will germinate, 115° F., and 91° to 93° F. as the temperature at which germination is most rapid.

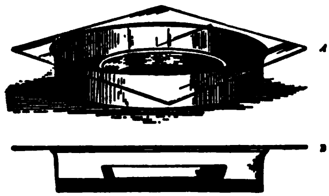
271. **Treatment of Seed.**—There are four purposes for which seeds have been treated with chemicals; viz., (1) to hasten germination; (2) to protect the seed from insects and other animal pests; (3) to prevent the attack of fungi, and (4) to furnish plant food. The evidence as to the influence of chemicals in all of these directions as relates to maize seed is more or less conflict-

1 N. Y. Rpt. 1886, p. 40.

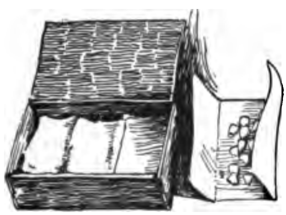
2 Bul. Torr. Bot. Club Vol. XXI, No. 8, p. 234.

ing, but in practice it is not generally desirable to treat the seed in any way.

272. **Method of Testing Seed.**—If the plumule and radicle of the embryo are carefully exposed by means of a sharp knife, these parts will be white and plump. Any discoloration or wilting is evidence of injured vitality. To determine vitality definitely, seed should always be tested before using. This may be done by any method which furnishes proper conditions of heat, moisture and air. A satisfactory method is to fill any receptacle similar in size and shape to a dinner plate with sand. Pour on water until it covers the surface of the sand. Gently drain off water. Place grains in the moist sand, thoroughly covering them, and cover receptacle by inverting a similar one over it to prevent too rapid evaporation and place in a temperature of 80° F. If ninety-five per cent of the seed fails to germinate in five days, the seed is unsatisfactory. If shelled grain is to be tested, take 100 grains after thorough mixing. If ears are to be tested, take three grains from each of twenty-five to fifty ears, taking a grain from butt, middle and tip. In some cases it may be desirable to test each ear separately by taking ten grains from each ear. In no case should an ear be used in which nine out of the ten grains failed to germinate under conditions named.



Homemade germinating apparatus: consists of a shallow tin basin, which is given two coats of mineral paint to prevent rusting. The bottom of the basin is covered with water and a small flat-bottomed saucer of porous clay is placed inside. Seeds are placed between two layers of moist blotting paper or flannel cloth. A, complete; B, section. (After Hicks.)


Cigar box used for testing germination of maize. Grains may be placed between moistened newspapers or cloths, preferably flannel. (After Holden.)

273. **Seed from Different Parts of the Ear.**—Grains on an ear equally represent inherent qualities of the plant which produced them. They should, under favorable conditions, produce plants having similar characteristics. The butt grains being larger and the tip grains smaller, differences in the food supply exist which it was thought might modify the ability of the seed to survive unfavorable conditions or cause variation in the vigor with which the young plant was started upon an independent existence. It has also been suggested that the grains on the middle of the ear are more likely to be fertilized with pollen from the same plant and that this closer breeding might tend to decrease the yield from plants grown from such grains. In no case have any considerable differences in yield been obtained from using grains from different parts of the ear. The results given below seem clearly to demonstrate that there is no advantage in planting grains from any special portion of the ear, provided equal stands are obtained.

**Average Yield per Acre of Seed from Different Parts of Ear—Bushels.**

| Station | Bul. | No. yrs. | Butt | Middle | Tip |
|---|---|---|---|---|---|
| Alabama | 111 | 3 | 15.4 | 16.3 | 16.8 |
| Arkansas | 22 | 1 | 34.2 | 30.8 | 30.6 |
| Georgia | 34 | 1 | 26.9 | 26.2 | 27.4 |
| Kansas | 64 | 5 | 39.7 | 38.5 | 39.0 |
| New York State | Rpt. '85 | 4 | 56.6 | 57.6 | 58.6 |
| Ohio | 78 | 9 | 58.9 | 59.3 | 58.7 |

The Kansas Station found that under field conditions eighty-six per cent of the butt grains, ninety per cent of the middle grains and seventy per cent of the tip grains produced plants.[1] The Iowa Station[2] found that when all the grains of an ear

1 Kan. Bul. 64, p. 238.

2 Iowa Bul. 68, p. 278.

were used in the corn planter, the number of grains dropped at one time varied from one to six grains, the planter dropping three grains to the hill sixty-six times out of a hundred. When only the middle grains of the ear were used, the planter dropped two grains eight times and three grains ninety-two times to each hundred hills. Since uniformity of stand is essential to maximum yield, it is therefore good practice to discard the largest of the butt and the smallest of the tip grains. It is also found that in order to secure uniformity of stand it is essential to select ears having grains of uniform size. It was found that when long and short grains were mixed together, the planter dropped three grains seventy-five times out of one hundred; while when planted separately with proper plates for each, the planter dropped three short grains ninety-five times out of one hundred and three long grains ninety-two times out of one hundred.

# XII.

## MAIZE.

### I. CLIMATE.

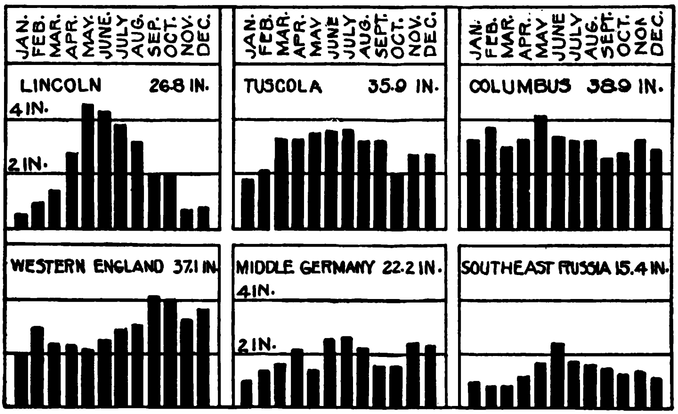
274. **Limited Distribution.**—That there is a wide difference in distribution of maize as compared with other cereals is shown in the following table giving average production in million bushels by continents for five years, 1898-1902 inclusive:

| | Maize | Wheat | Rye | Oats | Barley |
|---|---|---|---|---|---|
| North America | 2,149 | 717 | 25 | 944 | 124 |
| South America . | 86 | 96 | .... | .... | .... |
| Europe . . . | 471 | 1,580 | 1,470 | 2,103 | 788 |
| Asia . . | .... | 382 | 59 | 52 | 50 |
| Africa . . . | 32 | 45 | .... | 7 | 48 |
| Australasia . . | 9 | 48 | .... | 25 | 3 |
| Total . . | 2,747 | 2,868 | 1,554 | 3,131 | 1,013 |

The fact that sixty-six per cent of all the maize raised in the United States is grown in seven maize surplus States—Ohio, Indiana, Illinois, Iowa, Missouri, Nebraska and Kansas—is a further indication of its limited distribution. It is this limited distribution, coupled with the fact that maize will produce about twice the food nutrients of any of our other cereals per acre, that makes lands especially adapted to the culture of maize command relatively high prices.

275. **Causes Limiting Distribution.**—Among the causes limiting successful cultivation are temperature and sunshine, rainfall and physiographical features, including soil. It is only when these several factors are properly combined that the culture of

maize becomes commercially successful. The absence of any one may limit successful production. If, for example, the area between the 70° and 80° July isotherm be followed around the world in the northern latitude, it will be found that throughout the larger part of its course the rainfall is insufficient at those times of the year when it is most needed by the maize plant;



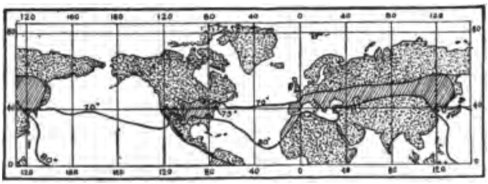

Variation in amount and distribution of normal monthly rainfall, see map (276). For May, June, July and August, total normal rainfall is: Lincoln, Nebraska, 15.7 inches; Tuscola, Illinois, 14.4 inches; Columbus, Ohio, 13.2 inches; Western England, 10.7 inches; Middle Germany, 8.6 inches; Southeast Russia, 7.2 inches.[1] The great maize belt lies between the longitudes of Columbus, Ohio (83° 0′ W. Long.), and Lincoln, Nebraska (96° 45′ W. Long.).

or, where the rainfall is sufficient, physiographical features prevent the culture of maize on a large scale.

The so-called "corn belt" of the United States appears to have the best combination of temperature, sunshine, rainfall, soil and topography for the production of maize of any considerable area in the world.

1 Rainfalls for Lincoln, Tuscola and Columbus are from twenty-five-year averages of the United States Weather Bureau. The European figures are from Davis' Elementary Meteorology.

**276. Influence of Temperature.**—It is the temperature during the maize growing months of May to September inclusive, rather than the average annual temperature, that influences the production of maize. It is not only the temperature of air and soil as expressed by the thermometer, but also the sunshine, the influence of which is not fully expressed by thermometric readings. Brewer[1] has shown that fifty-five per cent of the maize crop of 1879 in the United States was grown between July isotherms 75° and 80° F. and thirty-three per cent between 70° and 75° F., making a total of eighty-eight per cent between July isotherms 70° F. to 80° F.



Map showing area in Northern Hemisphere between July isotherms, 70° and 80° F., indicating suitable temperature for the production of maize. Note rainfall in chart (275).

It is difficult to give precise limits to an influence which is one of several absolutely necessary. Beale[2] has compared the yield of maize with the temperature in each of the nine leading maize producing States, viz., Ohio, Indiana, Kentucky, Tennessee, Illinois, Iowa, Missouri, Nebraska and Kansas, during the five months May to September inclusive for sixteen years. No relation in these favored States could be traced between yield per acre and temperature.

Temperature is well known to influence maturity and may thus, indirectly at least, affect yield of merchantable grain, especially in regions near the northern limit of successful culture. The New York State Station[3] compares the soil temperature with yield in crops of different maturity, as follows:

1 Tenth Census U. S., Vol. Agr.

2 H. G. Beale: Thesis, B. S. Degree, Ohio State University, 1902.

3 N. Y. Rpt. (Geneva) 1886, p. 39.

**Influence of Temperature Upon Maturity of Maize.**

| Maturity | Year | Mean soil temperature, degrees F. | Mean max. soil temp., degrees F. | Rainfall | | Yield, bu. |
|---|---|---|---|---|---|---|
| | | | | June-August | Sept.-Oct. | |
| Well ripened . | 1884 | 71.4 | 81.5 | 8.14 | 3.34 | 63.8 |
| Fairly ripe . . | 1882 | 67.8 | 80.1 | 8.91 | 1.83 | 50.2 |
| Rather moist but safe binned . . | 1883 | 63.5 | 76.1 | 13.53 | 4.64 | 58.6 |
| Very moist, moulding in bin . . | 1885 | 67.5 | 73.7 | 14.67 | 4.64 | 58.8 |

277. **Influence of Climate Upon Habit of Growth.**—There is greater variation in the habit of growth of the maize plant than in any other cereal. These variations within any one of the five types of maize seem to be correlated with the climatic conditions as indicated by the great variation in size and in the time of maturity in northern as compared with southern latitudes.

The growing season for maize varies in different sections of the United States from ninety to 160 days and varieties exist which are adapted to these different growing periods. In general it may be said that as we go north or south of a given latitude a variety becomes one day later or earlier for each ten miles of travel, the altitude remaining the same. That is to say, a variety which ripens two weeks before a killing frost in a given locality would only barely ripen if taken 140 miles farther north, the altitude remaining the same. Care should be taken, therefore, in selecting new varieties, to get them from the same latitude. If obtained from much farther north they may ripen too early and consequently be too small. If obtained much farther south, they may not ripen.

Size and period of growth are also influenced by moisture. Under conditions of favorable water supply, the plant continues to grow, while a deficiency will reduce growth and hasten ripening.

278. **Influence of Climate Upon Varieties.**—Whether the environment was a cause of variation or whether selection, it is probable

that there is a relation between climate and existing varieties of maize. The time that it has taken to fix these types is, however, a matter of much difference of opinion and about which the evidence is obscure. The variations as to size and maturity existed when this country was discovered. It is a common observation that the varieties of a given region tend to assume a common type. When dent varieties are introduced in a region growing flint varieties, or the reverse, the introduced variety tends to take on the characters of the other type. This has been attributed to climatic influences, but may be explained upon the grounds of crossing and unconscious selection. The current cross would not, ordinarily, show in the seed, but would show in the resulting crop. Varieties sufficiently distinct to escape cross-pollination have been grown continucusly without modification.[1]

The author had a standard variety of maize grown about 120 miles north of the Illinois Station for three years. The first season it barely ripened in its new location. The ripest ears were selected for seed, and in subsequent years it was believed by the grower to have ripened earlier. After three years seed was returned to the Illinois Station and on the fourth year grown beside seed continuously grown at the station. When thus grown side by side there was no difference in the time of ripening. The evidence concerning the influence of climate upon varieties is not as clear as might be desired, but it is probable that much that has been ascribed to climate has been due to selection.

279. **Influence of Climate Upon Composition.**—Analyses so far reported do not indicate any material difference in composition in maize grown in different sections of the country covering a wide variation in soil and climate. An average of thirty-five northern and forty-nine southern grown samples of dent maize has shown the following composition:

1 Cf. Bul. Torr. Bot. Club Vol. XXI (1894), No. 12, p. 521.

| | Northern | Southern |
|---|---|---|
| Ash | 1.7 | 1.7 |
| Protein (N x 6.25) | 11.8 | 11.5 |
| Fiber | 2.3 | 2.3 |
| Nitrogen-free extract | 79.1 | 78.7 |
| Fat | 5.1 | 5.7 |

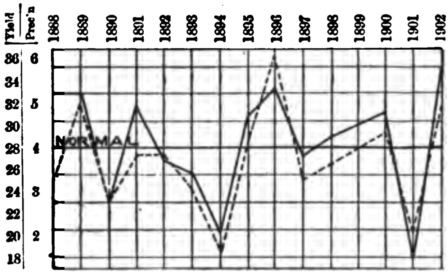
280. **Need of Water.**—At the Illinois Station, from eighteen varieties of maize on eighteen tenth-acre plats, the author obtained thirty-two bushels of dry shelled grain per acre. The next season, with the same varieties on the same plats, with cultural methods as nearly identical as possible, and without the addition of any fertilizer, ninety-four bushels per acre were obtained. During the first season, the rainfall for the five growing months (May to September) was thirteen inches; during the second, twenty-two and a half inches. During the same period the average temperature for the first season was 73° F.; the second, 69° F. (276)

The amount of water evaporated from the maize plant and the surrounding soil has been determined by King[1] to be in Wisconsin 270 pounds for each pound of dry matter grown, equivalent to a rainfall of 2.4 inches for each ton. This is only about half that required by oats and clover. Maize is, however, very greatly influenced by the water supply in July and August, since during that time the period of growth is very rapid. The author has determined the growth of maize in one week in July in Illinois to be equal to 1,300 pounds of dry matter per acre, which would require, according to the experiments of King, 1.5 inches of rainfall. (350) At such times, unless the physical conditions of the soil are the best, the plant is apt to suffer from a lack of water, or, in other words, from drouth.

281. **Influence of Rainfall.**—Everything points to the importance of water in the successful culture of maize. Beale has

[1] King: Physics of Agriculture, p. 139.

shown that while no relation could be traced between temperature and yield of maize, a very direct relationship could be traced between rainfall and yield. The yield did not depend merely upon the total rainfall for the five growing months of May to September, but much depended upon the distribution. The June, July and August rainfall had the greatest influence, and of these July was the most important. The September rainfall had no noticeable effect, while much rainfall and cloudy weather in April and May decreased the yield. A July rainfall of from 4.75 to 5.25, and a June, July and August rainfall of 11.75 to 12.25 inches, was found most desirable. The most favorable condition for the growth of maize is comparatively heavy rains at considerable intervals, with clear sunshiny weather in the meantime.




A comparison of the average rainfall for July and the average yield of maize in bushels per acre in Ohio, Indiana, Illinois, Iowa, Nebraska, Kansas, Missouri and Kentucky. (After J. Warren Smith.)
——— Average yield of maize in bushels per acre.
------ Average precipitation in July in inches.

### II. THE SOIL AND ITS AMENDMENTS.

**282. Soil.**—The yield of maize is greatly influenced by the character of the soil, perhaps even more so than any other cereal. Alluvial river bottom soil and tile drained swamps furnish the best conditions. A large proportion of the maize crop is grown on drift soil, but not all portions of the glaciated land are equally well adapted to this crop. (115) In the Southern States the red or chocolate-colored upland soils with red clay subsoils are better for maize than the gray soils with yellow clay subsoils.[1] For its best growth, maize requires a friable

[1] Ga. Bul. 46, p. 73.

soil that is easily drained and does not bake during drouth. While the water should drain freely from the surface, a water-table within three feet of the surface is not objectionable and probably desirable. The free movement of water through the soil in all directions, especially during the period of fastest growth, is essential to the largest yields.

283. **Rotations.**—The maize crop, while not considered an exhaustive crop, requires a fertile soil, that is, one with a high crop producing capacity. The rotation and fertilization are such as to bring this crop on the soil at the time of its greatest producing power. Throughout the main "corn-belt," a good rotation is, maize, two years; wheat or oats, one year; timothy and clover, three years. In the Northern States outside the distinctive "corn-belt," maize is grown only one year, generally followed by oats; then wheat seeded with timothy and clover. The length of time the seeding is left to stand is quite variable. Economic conditions have a controlling influence, but for the good of the land probably one to three years will give the best results. (119) The Louisiana Station[1] has decided that a three-year rotation, consisting of maize, oats, followed by cowpeas and cotton, is the best attainable for that section. To get the maximum yield, it is necessary to sow the oats in October. The cotton cannot be removed in time for the oat crop, but maize can.

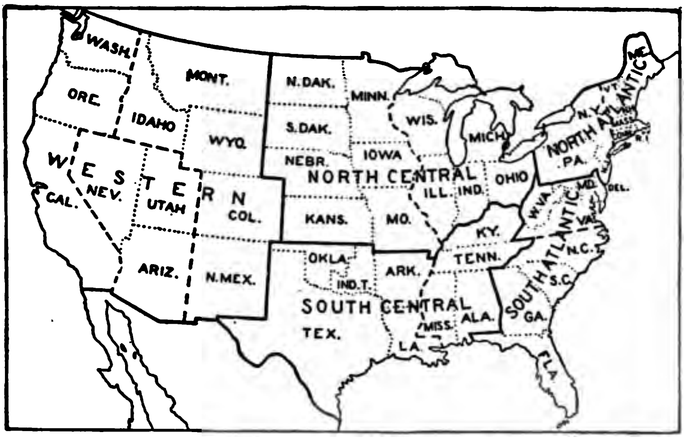
The Indiana Station[2] found that a rotation that included timothy and clover, beans and roots, gave during seven years a yield of twenty per cent more grain of maize than did a rotation containing only maize, oats and wheat. The last year the gain was forty-eight per cent, indicating a continuous widening in productive capacity.

284. **The Continuous Cropping of Maize.**—On deep black friable prairie soils, as well as upon the fertile river bottom soils

[1] La. Bul. 35, p. 1,211.

[2] Ind. Bul. 55, p. 28.

of the North Central States, maize has been raised continuously for many years with success when more or less frequent applications of stable manure have been made. The Illinois Station raised maize continuously for twenty years upon a black friable prairie soil. The average annual yield from the plat receiving no fertilizers was, during the last eight years of this period (1888-1895), 35.7 bushels; from the plat receiving commercial fertilizer, 35.6 bushels, and from the plat receiving stable manure, 47.3 bushels. A six-course rotation, maize, two years; oats, one year;




In referring to the different sections of the United States the nomenclature of the United States Census Bureau is followed, as shown above. Northern States include North Atlantic and North Central States, and Southern States include South Atlantic and South Central States.

and clover, three years, was carried out during twenty years as uniformly as the exigencies of the clover catch would permit. During the last eight years five comparisons as to increase of yield, both first year and second year after clover, could be made with the plat continuously in maize and receiving no fertilizer. The average increase the first year was twenty bushels and the second year 15.2 bushels per acre. In a similar comparison, where maize alternated with oats, the average increased yield as

compared with the plat continuously in maize without fertilizer was 2.6 bushels per acre.[1]

**285. Maintaining the Crop Producing Power of the Soil.**—The use of stable manure and the rotation of crops in connection with stock raising are the chief means of keeping the land in good condition to grow maize. Maize is not an exhaustive crop because (1) it removes from the soil comparatively small quantities of soil elements for food produced; (2) it produces large quantities of organic matter which when fed to live-stock makes large quantities of organic manure to return to the soil; (3) the intercultural tillage is doubtless beneficial, although this has not been as fully demonstrated as the expression of Jethro Tull,—"Tillage is manure,"—might indicate.

The Indiana Station[2] manured for two years a series of alternate plats which had grown maize continuously for five years with fresh horse manure amounting for two years to about fifty tons per acre. No manure was used before or since. During twelve years the average yield was nearly ten bushels per acre more on the manured than on the unmanured plats and on the last year of the period was nearly five bushels greater.

**286. Influence of Organic Matter.**—Stable manure is more frequently applied to land intended for maize than to any other. Grass and clover are usually followed by maize. One reason why stable manure is found generally beneficial for maize is that it supplies organic matter, which when in proper condition may modify the water content of the soil. Instances are known where no influence whatever was obtained from the use of large quantities of commercial fertilizers, but where the use of stable manure increased the crop. The Wisconsin Station found that while the total amount of water in the upper six feet of soil was essentially equal in both manured and unmanured

[1] Ill. Bul. 42, p. 177.

[2] Ind. Bul. 55, p. 29.

ground,[1] yet there was a marked difference in the distribution of it, the upper three feet of the manured ground being decidedly more moist than the unmanured. This may have been due to one or more of four reasons:

(1) The increased vegetable matter in the soil may cause more of the rainfall to be absorbed and allow less to run off the surface.

(2) Less water may be evaporated from such a soil, as indicated by laboratory experiments.

(3) The water may drain off into subterranean channels less rapidly.

(4) More water may be brought up from below by capillary attraction.

It is not unlikely that all four of these causes operated to produce the observed results.

287. **Application of Stable Manure.**—The amount of stable manure per acre may vary from ten to twenty tons. Where feasible, an ideal method is to apply the stable manure to the meadow in August and plow land late in the fall for the next spring's planting. For practical reasons, however, the manure is usually hauled in winter and spring and the manured land is then spring plowed. When hauling manure in the winter, care should be taken not to haul when the land will be seriously injured from puddling, and not to spread manure on top of a considerable thickness of snow lest it should run off suddenly and carry the manure with it. Well rotted manure will bring the most immediate results and the largest yield per acre, but hauling manure before much decay has taken place causes it to go farther, since there is considerable loss through decay. In regions or seasons of deficient rainfall the application of unrotted manure may cause a reduction in yield. The moisture in the soil being insufficient to cause decay, the undecayed organic

1 After making a correction for water used in producing the increased yield of maize upon the manured portion.

matter makes the soil drier, while if it had rotted either before or after being put on the soil, it would have increased the soil moisture. (286) The system of piling manure in the field and subsequently spreading it, while having the merit of securing substantially uniform distribution per acre, has fallen into disuse. It was found to be wasteful of labor and if the piles were left to stand for a considerable time, to cause unequal local distribution of the fertilizing elements. The manure is now usually spread from the wagon with a fork, or spread by means of a manure spreader. The latter are quite satisfactory so far as their work is concerned, but the amount of work required of a spreader is such as to cause those at present manufactured to lack durability.

288. **The Use of Commercial Fertilizers** for the production of maize has been the subject of field experimentation in at least twenty-six stations, principally in regions east of the Mississippi River. Many of these stations have found but very small increases from the use of commercial fertilizers, and most of them have not found profitable returns, especially west of the Alleghany Mountains. Practically all agree that the maize plant does not respond as readily to the use of commercial fertilizers as do the smaller cereals which are sown broadcast and thus have so many more plants to the acre, and which grow during a cooler portion of the year.

Where the soil requires it, from twenty to sixty pounds of phosphoric acid and from five to twenty pounds of nitrogen may be applied to the acre. Generally speaking, however, the best practice will be found to consist in relying upon the overturned sod and stable manure, with lime where needed to grow the maize and applying the commercial fertilizers to the wheat both to increase the yield of the latter and to promote the new seeding.

289. **Relative Importance of Fertilizing Constituents.**—The behavior of maize towards the different constituents of fertilizers

appears to be much the same as that of wheat. (121) In fact, so far as the cereals are concerned, the influence of the several ingredients of commercial fertilizers appears to be more dependent upon the soil than upon the crop. The following table gives the average yield of maize cut green for silage during fourteen years at Ottawa, Canada, when grown continuously on the same plats:[1]

| No. of plats | Treatment | Tons of green fodder |
|---|---|---|
| 2 | Unmanured | 8.02 |
| 3 | Phosphorus | 9.04 |
| 2 | Nitrogen | 11.40 |
| 2 | Potassium | 9.02 |
| 2 | Phosphorus and nitrogen | 11.01 |
| 2 | Phosphorus and potassium | 11.03 |
| 5 | Phosphorus, nitrogen and potassium | 11.97 |
| 2 | Barnyard manure (mixed horse and cow) 12 tons | 14.32 |

Fertilizers applied each year from 1888 to 1898 or 1899. No fertilizer used since. Clover sown in 1900 in place of maize and plowed under in May before maize was planted.

290. **Methods of Applying Fertilizers.**—While commercial fertilizers may be applied broadcast, this method is not generally advisable. Some maize planters have fertilizer attachments which apply the fertilizer with the seed. Where a wheat drill is used for drilling maize, it is a common practice to drill the fertilizer through the hoes on each side of the hoes drilling the maize, thus placing the fertilizer in the soil seven inches on each side of the maize row. (305)

291. **Influence of Season on Efficiency of Fertilizers.**—At the Illinois Station where maize was raised continuously for twenty years on manured and unmanured plats (284) in certain seasons of deficient rainfall the unmanured plat gave greater yield than that receiving annually stable manure. At the Indiana Station[2] both stable manure and commercial fertilizers used continuously for five years gave the best yields during seasons of high rainfall

1 Canadian Experimental Farms Rpt. 1902, p. 34.

2 Ind. Bul. 55, p. 29.

and the least returns during a season of low rainfall, the commercial fertilizer causing a decrease in yield. Other things equal, the best results from the use of fertilizers may be expected in regions or seasons of high rainfall.

292. **The Use of Lime.**—In those sections where lime is used, it is generally applied to land intended for maize, this appearing to be the best place in the rotation for its application. Wheeler has reported, however, that the use of lime may be injurious to the growth of maize where the nitrogen in the soil is principally in the form of nitrates, but where the soil is very sour and nitrates are not employed its use immediately before this crop may prove of great service.[1] In ordinary rotation the lime would be applied to sod land, although sometimes applied to oat stubble, or even maize stubble, where maize follows maize. Usually the best results follow its use upon sod land of rather long standing.

Calcium lime (CaO) is generally used and is to be preferred, although magnesian lime (MgO) is also used to a considerable extent with apparently satisfactory results. Besides increasing the per cent of calcium in the soil, lime makes adhesive soils more friable and granular, perhaps by causing a rearrangement and cementing together of the soil grains; makes sandy soil more retentive to organic matter; corrects the acidity of the soil in case any exists, thus creating a favorable condition for the growth of nitrifying organisms; may make potassium and phosphorus more available; hastens decomposition of organic matter; and while making the nitrogen in organic matter more available, may cause a more rapid loss of total nitrogen;—there is an old proverb, "Lime enriches the father but beggars the son." Where it is necessary to use lime, it should be accompanied by a liberal use of stable manure.

293. **Indications of Need of Lime.**—The need of lime may be

[1] R. I. Bul. 46, p. 95.

indicated (1) by the per cent of lime (CaO) present;[1] (2) by the acidity of the soil, which may be determined in quite sour soils by bringing the moist soil into contact with neutral litmus paper under proper precautions;[2] (3) by the excessive adhesiveness of clay soils; (4) by the character of the vegetation, or a change in the characteristic vegetation, or (5) by the persistent failure of certain crops, such as clover and beets. The most satisfactory method, however, of determining the need of lime is by applying it under conditions which make it possible to tell whether there is any increase of crop due to liming.[3]

294. **The Application of Lime.**—The equivalent of from one to four tons or from twenty-five to 100 bushels of quick lime (CaO) may be applied to land intended for maize. Ordinarily the amount should not exceed fifty bushels.[4] (122)

The freshly burned (quick) lime may be applied directly to the field, where it soon slakes, after which the land may be plowed, care being taken not to plow too deep. Unless it is ground, however, it is difficult to spread quick lime evenly. In order to reduce it to a fine powder the lime may be put in piles of two or three bushels at any convenient time in the fall, where the air, rains and moisture from the soil slake it. Better results will be obtained if the ground is scraped off down to moist soil where the lime is placed and the pile covered with moist soil. If the soil is dry, a half pail of water may be added to each pile. As soon as possible, the piles should be spread with a shovel and the land plowed. Although more laborious, it is better to apply the slaked lime to the plowed land in the spring and

[1] For agricultural crops, 0.2 per cent is usually considered the minimum requirement. This can be determined only by chemical analysis.

[2] R. I. Bul. 46, p. 100.

[3] For full discussion on the use of lime, see The Agricultural Use of Lime in Pennsylvania. By Dr. William Frear, 6th Ann. Rpt. Penn. Dept. of Agr. (1900), pp. 193-353.

[4] The legal weight of a bushel of lime varies in different States from seventy to eighty pounds.

harrow it in. It takes less lime, the lime is nearer the surface, and, if water-slaked in a large pile, it is in a much finer powder. While there is a difference of opinion as to the practical differences between the causticity of quick lime ($CaO$), water-slaked lime ($Ca(HO)_2$), and air-slaked lime ($CaCO_3$), all seem agreed that fineness is a positive advantage. The slaked lime may be spread from a wagon with a shovel, or a manure spreader with lime attachment may be used. Finely ground quick lime is now placed upon the market, and may be applied with a grain drill or a lime spreader.

295. **Irrigation.**—While alfalfa, wheat, potatoes and many fruits and vegetables have been abundantly raised by irrigation in America, maize has nowhere been extensively grown by this means. The yields of maize in the arid region under irrigation so far as reported do not compare favorably with yields in humid regions without irrigation.

The Wisconsin Station[1] has studied the influence of irrigation in the humid region. During eight years, ending 1901, the average yield of maize silage containing thirty per cent of dry matter was 17.2 tons with irrigation and 12.3 tons without irrigation, on land of moderate fertility. Wherever comparisons were made the increase in grain was greater than the increase in total dry matter. The average amount of water added per year was five inches. King concludes that "well managed irrigation in climates like that of Wisconsin may increase the yield of maize silage 40 to 45 per cent, and that of ear corn from 50 to 60 per cent as a general average." On coarse sandy soils in Wisconsin, water alone produced much better results than stable manure alone, but both together had much the greatest effect.[2] In 1902, the yield during a cold wet season without irrigation was greater than on comparable plats in the hot dry season of 1901 with irrigation. It was also found that the yield was greater on land that had not been irrigated the previous year, the reduction being greatest on manured land.[3]

[1] U. S. Dept. of Agr., O. E. S. Bul. 119, p. 315.

[2] U. S. Dept. of Agr., O. E. S. Bul. 119, p. 326.

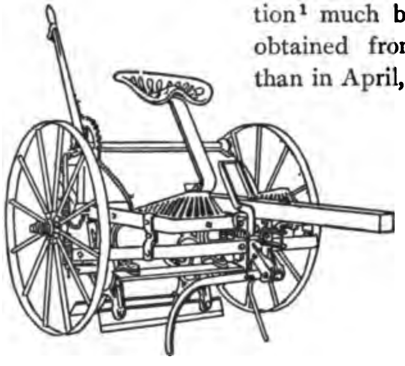
[3] Wis. Rpt. 1902, p. 187

# XIII.

## MAIZE.

### CULTURAL METHODS.

296. **Time of Plowing.**—The evidence appears conclusive that the question of time of plowing relates to economic farm management rather than to differences in comparative yields. The experimental evidence on the subject of fall and spring plowing is meager and inconclusive. At the Nebraska Station[1] much better yields of grain were obtained from plowing in September than in April, but no material difference was obtained from plowing in November than April. There are fine clay soils which become during the winter, if fall-plowed, so hard and compact as to make the preparation of a suitable seed bed at planting time a difficult task. Usually, however, the frosts of winter have a mellowing influence and increase the ease of preparing the seed bed. As fall plowing seldom affects the yield adversely, at least, it is generally good farm practice to plow in the fall those areas to which manure is not to be applied during winter and spring. Early plowing in the spring as compared with late plowing tends to conserve the soil moisture both by preventing evaporation of water and by increasing the amount of rainfall held.



Single row stalk cutter used for cutting up stalks, where maize follows maize, to prevent stalks from interfering with the operation of the cultivator.

1 Neb. Bul. 54.

Quiroga has shown that early plowing as compared with late plowing may not only increase the percentage of moisture in the soil and the yield of maize, but that the nitric nitrogen in the soil may be considerably increased. The available nitrogen in parts per million of dry soil was found to be as follows:[1]

| Month | Early plowed | Late plowed |
|---|---|---|
| April | 1.43 | 1.33 |
| June | 7.34 | 4.68 |
| July | 7.62 | 4.92 |
| August | 4.08 | 2.06 |
| September | 2.12 | 1.19 |
| Season April to September | 4.51 | 2.83 |

On the other hand, early plowing decreases the amount of organic matter which will be incorporated in the soil if the land is in sod or a cover crop. Where the land is badly infested with perennial weeds, such as the bindweed or morning glory, late plowing destroys the growth already started and gives the maize plant a chance at least to start even. When the land is plowed immediately before planting, it may be at once dragged or rolled and then harrowed and planted while the surface is still fresh and moist. When the plowing is done earlier in the spring the surface requires working at once to prevent it from becoming hard, thus generally increasing the amount of labor to get a good seed bed.

**297. Depth of Plowing.**—While the variation in the depth of plowing seriously influences the cost of raising maize, since the draft of the plow is nearly proportional to the amount of soil turned, yet the investigations on this subject are quite unsatisfactory. In only one instance has a station reported results on depth of plowing for more than one year upon the same land. Undoubtedly the best depth will vary with the soil, the climate, the season, often with the previous crop grown, and the applica-

[1] Ohio State University Bul. Series 8, No. 28.

tions made (291); but no rules can be laid down as a guide for general practice. The following table gives the results of trials on widely different soils under widely differing climatic conditions:

| Station | Depth of plowing, inches | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | 12 |
| Illinois[1] . . . . . . | 52.9 | 69.4 | 69.3 | 71.7 | .... | .... |
| Illinois . . . . . . | 54.0 | .... | 57.5 | .... | 56.0 | .... |
| Indiana (ave. 3 years) . . | .... | 39.5 | 40.5 | 42.3 | 41.8 | 42.0 |
| Pennsylvania (ave. 3 years) . | .... | 47.0 | 62.0 | 57.5 | 58.5 | .... |
| New Hampshire[2] . . . | .... | 14.2 | 26.2 | 29.4 | 28.2 | .... |
| Alabama (Canebrake Sta.) . | .... | 24.1 | .... | .... | 24.2 | .... |
| Minnesota . . . . . | .... | 65.8 | 64.4 | 59.5[3] | .... | .... |
| Ohio[4] . . . . . . | .... | 43.1 | .... | 42.9 | .... | .... |
| Nebraska . . . . . | .... | 38.5 | .... | 31.0 | .... | .... |

In all cases the plowing was done in the spring, except at the New Hampshire Station, when the land was plowed November first. In the first trial at the Illinois Station, in place of the usual intercultural tillage, the weeds were removed by scraping with a sharp hoe with the least possible disturbance of the soil. An adjacent plat, not plowed but disked one inch deep, yielded 56.4 bushels of grain. The land on which this experiment was conducted had not been plowed in two years.

At the Pennsylvania Station a timothy and clover sod was plowed. At the four-inch depth the sod did not cover well and the shallow cultivation (two inches deep) which all plats received did not eradicate the grass on plats plowed only four inches deep.

While in a number of trials satisfactory results have been obtained by plowing four inches deep and less, yet the most generally satisfactory depth, all things considered, would seem to be six inches. As compared with wheat and oats, deep plowing is advisable.

[1] All results are in bushels of grain per acre, except in the case of New Hampshire, where tons of green fodder are given.

[2] Depths were 3, 5, 7 and 9 inches.

[3] Also subsoiled 6 inches deeper.

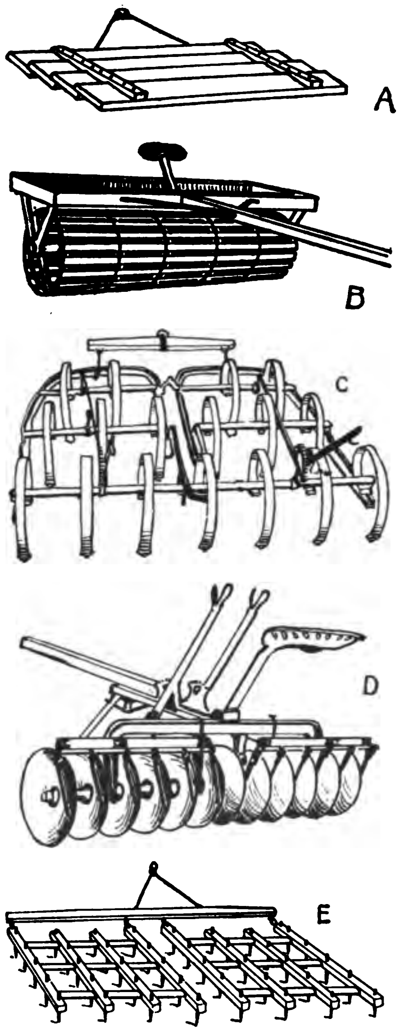
[4] Depths were 3 and 7 inches.

298. **Subsoiling**, or the loosening of the subsoil without bringing it to the surface, usually to a depth of twelve to eighteen inches, has been tried by a large number of stations. In some cases benefits; in other cases injury, both generally slight, but in most instances no material difference, has resulted. Subsoiling is nowhere a common practice, and the experiments so far conducted would lead to the conclusion that it will be found profitable for maize in humid regions only in exceptional cases. Indeed, in humid regions there is danger of puddling the subsoil, especially in the spring, where the subsoil may be quite wet while the surface soil is in condition to plow. In a co-operative test with fifty-nine farmers for three years, the Nebraska Station[1] concludes that in Nebraska subsoiling is beneficial on clay subsoils and useless or injurious on loam subsoils.

299. **Preparing the Ground After Plowing.**—Fall-plowed land is left without further preparation until spring, as this exposure aids weathering and the absorption of moisture. As soon as the surface begins to dry out in the spring it may be pulverized in order to give it a mulch, and thus prevent the soil from drying out and becoming hard. When land is spring-plowed, the upturned clods will, during a dry time, become exceedingly hard and difficult to pulverize. To prevent this, the surface should be pulverized before the drying has proceeded too far. Usually it is best thus to treat each day's plowing on the day it is done. This may be done with a wooden drag, a smoothing harrow, or even a roller.

A deep loose seed bed, with all large lumps pulverized, is desirable, but fineness of pulverization is not so important as in wheat. The three tools most generally useful in preparing the seed bed are the wooden drag, the disk harrow and the light smoothing harrow. The roller may replace the drag, and the spring tooth harrow may replace the disk harrow, especially on

1 Neb. Bul. 54.




Tools for preparing seed bed. A, wooden drag; B, tubular roller; C, spring tooth harrow; D, disk harrow; E, spike tooth harrow.

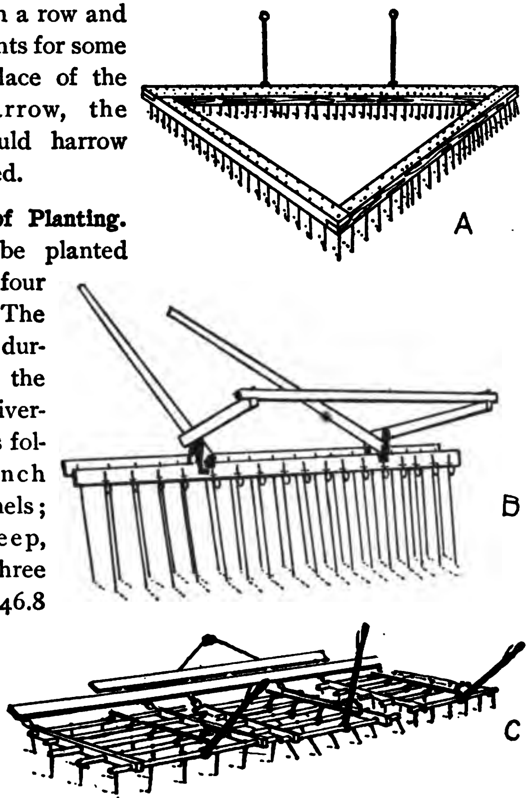
stony ground. Precise rules cannot be laid down as to number of times or the order in which these tools will be used, since this will depend largely upon the character and condition of the soil, which must be determined upon the spot.

Very much depends upon performing each tillage operation when the soil is in just the right condition. Two hours of sunshine will often make the difference between success and failure in the operation of a tillage implement. This is what is meant in part by the couplet:

He that by the plow would thrive
Himself must either hold or drive.

After the maize is planted, the land should be harrowed once, at least, with the smoothing harrow before the plant is out of the ground, and on many soils may be successfully harrowed after plants are well up. This second harrowing should not be given just when the maize

is coming, but after it is well up. When planted in drills it is best to harrow crosswise of the drills instead of with drills. When harrowing with the drills a harrow tooth will sometimes get started down a row and drag out the plants for some distance. In place of the smoothing harrow, the weeder or Gould harrow (A) may be used.




Tools for stirring soil before or soon after maize is up. A, homemade harrow, consisting of three pieces of 2 x 4, each seven feet four inches long, and eighty sixty-penny wire spikes. Traces of one horse to be hitched directly to flexible attachments indicated in order to give harrow vibratory motion; B, weeder; C, adjustable smoothing harrow.

**300. Depth of Planting.**—Maize may be planted from one to four inches deep. The average yield during six years at the Ohio State University has been as follows: One inch deep, 57.9 bushels; two inches deep, 51.2 bushels; three inches deep, 46.8 bushels.[1] Four seasons the results favored one inch deep, while during two seasons, when rainfall was about two-thirds normal, two inches gave the best results. At the Illinois Station the average yield during

[1] Ohio Rpt. 1890, p. 57.

five years was as follows: One inch deep, 78 bushels; two inches deep, 72 bushels; three inches deep, 65 bushels; four inches deep, 69 bushels; five inches deep, 61 bushels; six inches deep, 60 bushels.[1] This experiment was on soil much more favorable to deep planting than the average. In three years the best results were obtained at one inch, one year at four inches, and one year at six inches, this last being due to an exceptional period of drouth subsequent to planting. At the Ontario Agricultural College during four years, better yields were obtained at two and three inches deep than at shallower or deeper planting.[2] At the New York Station planting between two and eight inches deep caused a loss of seed germination as compared with shallower planting, but the yield per stalk was about the same at all depths.[3]

When planted by machinery, it is usually necessary to plant some of the seed somewhat deeper than one inch in order that all may be covered an inch deep. Hence the desirability of a uniform seed bed. Where it is the practice to harrow the land after planting it is probably better to plant deeper than one inch so as not to move or drag out the hills. The depth of planting has merely to do with the plant getting properly started. If the seed germinates equally well, no difference in yield need be expected on account of depth of planting. Nothing is gained by deep planting, unless necessitated by dryness of soil or practical considerations just mentioned. It only requires of the plant greater time and effort to reach the surface. The depth of roots is not materially affected by depth of planting. (52)

301. **Listing.**—There is a method of planting known as listing practiced in those States where the soils are friable and the rainfall scanty. Shelton wrote in 1888:[4]

1 Ill. Bul. 31, p. 353.
2 Ont. Agr. and Expt. Farms Rpt. 1902, p. 133.
3 N. Y. State Rpt. 1882, p. 51.
4 Kan. Rpt. 1888, p. 25.

"At the present time nearly or quite three-fourths of Kansas corn is raised by the method known as listing; which, I may say in explanation, consists of drilling the seed in the bottoms of deep furrows struck at the usual intervals in ground not otherwise plowed.

"It is claimed that listed corn endures dry weather much better than the surface planted; that it gives increased yield and this especially that the labor of growing a crop of corn is reduced one-fourth to one-third by the new method."

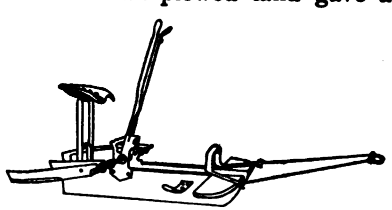
Kansas Station has reported six, Oklahoma Station two tests of listed maize as compared to that surface planted, as follows:

| State | Year | Surface | Listed |
|---|---|---|---|
| Kansas | 1888 | 41 | 46 |
| Kansas | 1889 | 86 | 89 |
| Kansas | 1892 | 26 | 25 |
| Kansas | 1893 | 28 | 26 |
| Kansas | 1895 | 15 | 17 |
| Kansas | 1896 | 37 | 47 |
| Oklahoma | 1894 | 10 | 15 |
| Oklahoma | 1896 | 32 | 28 |
| Average | | 34.4 | 36.6 |

Five out of the eight trials of listed maize gave the best results and on the average of the eight trials the yield was six per cent greater than when surface planted.

At the Illinois Station[1] maize listed on fall plowed land gave a

Combined sulky lister and planter; makes furrow in unplowed ground, drops and covers seed at the same time. In some cases disks are used in place of shovels to cover the seed.



Cultivator for listed maize; also made with disks in place of knives. Forms are made which cultivate two rows at one time.

[1] Ill. Bul. 37, p. 24.

yield of fifty-one bushels as compared with fifty-six bushels on an average of ten adjacent plats when surface planted.

302. **Time of Planting.**—The soil should be at least 60° F. at the depth of the seed before maize is planted. But it is not enough to consult the thermometer; the almanac should also be consulted. A change in the weather may follow even after the temperature of the soil is 60° F. The old Indian sign, which is to plant maize when the leaves of oak trees are as big as a squirrel's ear, is not much at fault. The best date of planting will of course vary largely with the season. The following table gives the best dates as determined at the stations indicated, as well as indicating the period over which the test was made.

**Results from Planting at Different Dates.**

| Station | Seasons | Earlies | Best | Latest |
|---|---|---|---|---|
| Illinois . | 8 | Apr. 22-26 | May 11-18 | June 17-22 |
| Indiana . | 7 | May 1-2 | May 1-8 | May 28-30 |
| Kansas . | 2 | Apr. 18-20 | May 1 | May 29-30 |
| North Dakota | 1 | May 18-25 | June 1-8 | June 15-July 2 |
| Ohio . . | 7 | Apr. 26 | May 14-24 | June 4-12 |
| Oklahoma . | 2 | Mar. 21-28 | Mar. 28-Apr. 18 | Apr. 25-May 13 |
| South Dakota | 3 | May 1 | May 15-25 | June 10 |

There is fairly good evidence that in the main maize belt there is a period of three to four weeks within which the time of planting does not materially affect the yield. At the Illinois Station, for example, while the best results during an average of eight years were obtained from May 11th to May 18th, there was but little difference in yield from May 4th to June 1st. Very early planting, however, has been shown to require more cultivation to keep the land free of weeds. On the other hand, it is not wise to delay planting when the conditions are favorable for fear that subsequently climatic conditions may be such as to prevent the planting at the theoretically best time. Where

maize is planted on old sod land, it is frequently advisable to delay planting in order to avoid cut worms and other allied insects. (329)

303. **Rate of Planting.**—In securing maximum yields of grain and stover very much depends upon the rate of seeding and the uniformity of distribution. The thickness of planting depends upon the soil, the climate, the variety and the purpose for which it is grown. In some of the Southern States maize is planted in hills five feet apart and one stalk produced per hill. In the New England States it is planted 3.5 feet apart and three to four stalks are raised per hill. In one experiment at the Georgia Station[1] a larger yield of maize was obtained where 2,184 stalks were raised per acre than by thicker planting. In another experiment at the Connecticut Station[2] a greater yield of grain and of water-free fodder was obtained with 21,780 stalks per acre than by thicker or thinner seeding. In other words, the best results with dent maize were obtained in Connecticut with ten times as thick planting as in Georgia. These results are doubtless unusual, but they indicate possible extremes.

The Illinois Station tested for three years six rates of seeding ranging from 5,940 grains to 47,520 grains per acre; and for five years rates ranging from 9,504 grains to 47,520 grains per acre. Five plats of each rate were planted each year under different methods of distribution. The size of the whole plant and of the ear increased uniformly as the planting became thinner. The proportion of ears to stalks also increased. The total weight of fodder increased uniformly as the planting increased in thickness. The total weight of grain was greatest two years when 23,760 grains were planted; two years when 11,880 grains were planted, and one year when 9,504 grains were planted. In this last instance the total yield was small, the season being exceptionally unfavorable for maize. The

[1] Ga. Bul. 10, p. 148.

[2] Conn. Rpt. 1889, p. 16.

thickest seeding gave the best results when the general average of all plats was highest. The greatest average yield of grain for five years was when 11,880 grains were planted. The total average yield of grain for five years was not greatly affected by rates of seeding varying from 9,504 to 23,760 grains per acre; but the size of the ears was markedly different, the average weight of ears being from one-third to one-half greater in the thinner planting. The following table of results obtained at the Illinois Station for three years (1888-1890) illustrates relationships which have been more or less completely verified by other stations which have investigated this subject.[1]

| Rate of planting | Weight of 100 ears, lb. | Weight of 100 stalks (stover), lb. | Weight of shelled maize per acre, bu. | Tons stover per acre |
|---|---|---|---|---|
| 47,520 . . . . . . | 24 | 29 | 59 | 4.8 |
| 23,760 . . . . . . | 39 | 40 | 76 | 3.7 |
| 15,840 . . . . . . | 51 | 45 | 77 | 3.1 |
| 11,880 . . . . . . | 59 | 51 | 81 | 3.0 |
| 9,504 . . . . . . | 62 | 55 | 72 | 2.9 |
| 5,940 . . . . . . | 66 | 66 | 55 | 2.5 |

The more favorable the soil and climatic conditions are for large yields of maize, the thicker the planting should be. At the Illinois Station a seeding which produced from nine thousand to twelve thousand ears per acre brought the largest yield of grain when the conditions favored a general yield of seventy-five bushels or more; and a seeding which produced from eight thousand to nine thousand ears per acre gave the largest yield of grain when the conditions favored a general yield of forty to sixty bushels. Although varying somewhat with the rate of planting, within ordinary limits about three grains were planted for each two ears harvested. At the Missouri Station,[2] on good land, the largest yield, seventy bushels, was

1 Ill. Bul. 13, p. 410.

2 Mo. Bul. 32.

obtained by leaving four stalks in hills three feet nine inches apart each way, or 12,960 stalks per acre, while on poor land the largest yield, thirty-six bushels, was from two stalks per hill, or 6,480 stalks per acre.

For the principal maize belt, planting at the rate of one grain every twelve inches, or approximately four grains per hill in rows three feet eight inches apart, has given the best results where only grain is desired; at the rate of one grain every nine inches where both grain and stover are desired, the grain being considered the principal product, and at the rate of one grain every six inches where it is planted for silage or where maize fodder is to be fed without husking. Where maize is intended for soiling to be fed early in the season before ears have been formed, the planting should be at the rate of one grain every three inches, as the development of the individual plant is not seriously retarded by this thicker planting up to this period of growth. These general relationships will probably hold for regions further north or south, but the absolute rate will vary.

304. **Influence of Rate of Seeding Upon Composition.**—Analyses show that when there is no greater variation in rate of planting than that of one grain every six to twelve inches that there is no material difference in the composition of the fodder, but where excessive amounts of seed are planted the protein is materially decreased, and the percentage of crude fiber considerably increased.

At the Connecticut Station,[1] with flint and dent maize planted at six rates of seeding varying from 2,720 to 87,040 plants per acre, the per cent of ash and protein (Nx6.25) was greatest when the stand of maize was thinnest, and decreased regularly up to the thickest planting. This difference was small in the ash but large in the protein. The per cent of fiber was greatest in the thickest planting but the relation between the per cent of fiber and the rate of seeding was not entirely uniform. In both varieties the percentage of nitrogen-free extract was greatest when there were 21,760 plants per acre. In both varieties, that thickness which gave the largest yield of dry matter also gave the greatest yield of nutrients,

[1] Conn. Rpt. 1899, p. 9.

except in dent maize, where the fiber was the greatest at the thickest planting; while the total yield of dry matter was greatest where 21,760 plants were harvested per acre.

At the Maine Station [1] seeding at rates varying from 12,446 to 24,891 grains per acre was found to produce no marked difference either in yield of total dry matter or in composition.

The New Hampshire Station [2] found no marked difference in composition with a flint variety between planting at ten quarts and one bushel of seed per acre, but with a dent variety found a much larger percentage of protein and a considerably smaller percentage of crude fiber when one-half bushel of seed was used than when two bushels were used.

The Pennsylvania Station [3] found no marked difference in composition between seeding a dent variety at eighteen and forty-two pounds of seed per acre, or a flint variety at twenty-one and fifty-five pounds per acre.

[1] Me. Rpt. 1896, p. 31.

[2] N. H. Bul. 92.

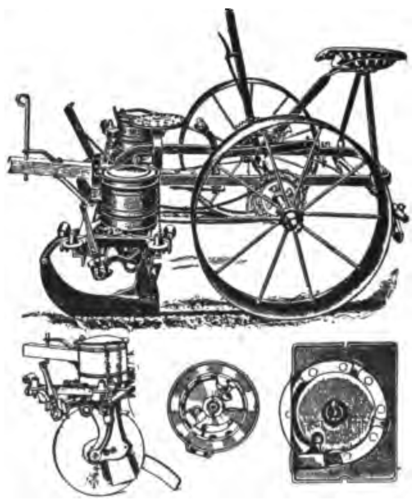
[3] Penn. Rpt. 1891, p. 30.

# XIV.

## MAIZE.

### CULTURAL METHODS (CONCLUDED).

305. **Planting in Hills or Drills.**—The Indian method of planting maize was to plant four grains in a hill four feet each way. This method they taught to the colonists. The usual method in the North Atlantic States is to plant in drills; in the North Central States the practice is divided, but the larger part is planted in hills; in the Southern States it is usually planted in hills on the low level lands, while on hill lands the maize is drilled, in order that all cultivation may be at right angles to the slope of the hill, and thus prevent washing. The chief reason why maize is planted in drills in the North Atlantic States is that on account of the unevenness of the surface the check rowing planters do not readily check straight



Two-row maize planter; seed can be planted either in hills or drills. Below on the left is shown a disk in place of shoe as a furrow opener. On the right are two forms of rotary plates for dropping the seed. In the form on the right the number of grains dropped at one time depends upon the size of the holes in the plate; in the form shown in the center, the fact that grains of maize are all practically the same thickness, no matter how much they vary in length and width, is taken advantage of to select the grains singly, the number per hill depending upon the rate at which the plate revolves.

cross rows, and that on account of the comparative smallness of the fields a one-horse machine will drill maize rapidly enough, and can be bought for from ten to twelve dollars; while a two-horse maize planter, such as is found economical in the larger and more level fields in the North Central States, will cost from thirty to forty dollars. The wheat drill is also frequently used in the North Atlantic States for planting maize. If the third hoe from each end of a wheat drill having eleven hoes, each seven inches apart, is used, maize will be drilled in rows three feet six inches apart, and the wheels will be twenty-one inches from the drill row, thus serving to mark the land. The differences in method relate to economical farm management, rather than to any material difference in the growth of maize. It is only a question by which method maize may be raised at the least cost, and at the same time given the most effective cultivation.

One-row maize drill with fertilizer attachment.

306. **Method of Distribution.**—Fifteen stations have experimented on the influence of the method of distribution of seed, the amount of seed per acre remaining the same, and all have found either no difference or comparatively small differences due to methods of distribution. Experiments have been conducted at the Illinois Station[1] for five years. Plats were planted at five rates of seeding, ranging from 9,504 to 47,520 grains; and at each of these rates of seeding at four methods of distribution: namely, one, two, three and four grains in a place. For three years five grains to a hill were planted. For example, one grain every twelve inches, two grains every twenty-four inches, three grains every thirty-six inches and four grains every forty-eight inches. While the rate of thickness (303) modified the yield of grain and stover, as well as the develop-

[1] Ill. Bul. 31, p. 354.

ment of the individual plants, it made no material difference in the development of the individual plant, the size of the ear, the yield of grain or of stover, and hence the proportion of grain to stover, whether one, two, three, four or five grains were planted in a place, provided the number of grains planted per acre was the same, the least distance between hills being three inches, and the greatest being forty-eight inches, in rows three feet eight inches apart. The following table shows the yield of grain for five years, plats having been averaged so as to eliminate the influence of rate of seeding.

| Grains per hill or place | Bushels per acre of air dry grain | | | | | |
|---|---|---|---|---|---|---|
| | 1888 | 1889 | 1890 | 1892 | 1893 | Average |
| 1 | 80 | 67 | 47 | 88 | 39 | 64.1 |
| 2 | 78 | 71 | 46 | 84 | 38 | 63.5 |
| 3 | 73 | 71 | 46 | 87 | 42 | 63.8 |
| 4 | 78 | 68 | 43 | 89 | 42 | 64.0 |

At the Maryland Station experiments have been conducted during five years with one stalk each twenty-two and a half inches in rows three feet nine inches apart as compared to two stalks per hill three feet nine inches apart. The following table shows the yield to have been slightly in favor of drilling every year both in yield of grain and stover:

| Year | Yield of grain, bushels | | Yield of stover, pounds | |
|---|---|---|---|---|
| | Drilled | Checked | Drilled | Checked |
| 1894 . . . . . . | 62.8 | 58.7 | 3,291 | 3,190 |
| 1895 . . . . . . | 35.8 | 33.2 | 2,349 | 1,824 |
| 1896 . . . . . . | 49.8 | 42.8 | 2,675 | 1,920 |
| 1897 . . . . . . | 50.4 | 49.1 | 1,792 | 2,142 |
| 1898 . . . . . . | 54.6 | 54.1 | 2,987 | 2,894 |
| Average . . . . . | 50.7 | 47.6 | 2,618 | 2,394 |

The Connecticut Station[1] found the composition of the crop practically the same, whether planted in hills or drills. Doubtless in some instances increased yields which have been attributed to planting in drills have been due to increased rate of seeding and not to the method of distribution. Where deep culture is practiced, however, drilling doubtless lessens the injury from root pruning (311), although at the same time tending to increase the growth of weeds. (309)

307. **Distance Apart of Rows.**—While a large number of experiments have been made to determine the advisability of planting in hills or drills, but few experiments have been made to determine the best distance or the limit of distance between rows. The distance apart of rows usually varies from three feet six inches or less in the extreme North to six feet or more in the South. Probably more maize planters are sold which plant three feet eight inches apart than any other distance. From experiments which have been conducted it is doubtful whether greater yields of dent maize can be obtained with rows three feet six inches apart than with rows three feet eight inches apart, provided the same amount of grain is planted per acre. On the other hand, the labor of cultivation is increased about five per cent.

The Georgia Station spaced single plants of dent maize four by three feet, five by two and four-tenths feet, and six by two feet, thus securing the same number of plants per acre, and obtained seventeen, sixteen and five-tenths, and sixteen and one-tenth bushels per acre respectively.[2] At the Alabama Station[3] slightly better yields were obtained with single plants three feet nine inches apart in rows four feet apart than with single plants three feet apart in rows five feet apart. The station, however, recommends rows five feet apart, both on account of the cheapness of cultivation and because it facilitates the raising of a row

[1] Conn. Rpt. 1890, p. 183.

[2] Ga. Bul. 46, p. 68.

[3] Ala. Bul. 88, p. 500.

of cowpeas between the rows of maize, which practice is recommended for poor land.

308. **Intercultural Tillage.**—The cultivation of maize during its early development prevents the growth of weeds and stirs the soil. The destruction of the weeds is made necessary by the fact that comparatively few plants are raised per acre and that it takes these plants from four to eight weeks to occupy the soil and shade the ground sufficiently to check the growth of weeds. The small grains quickly occupy the soil and prevent the growth of weeds. The tillage of these cereals has not in most instances been found to increase the yield. (136) This fact, in itself, suggests that killing the weeds is the most important purpose of tillage.

309. **Injury Due to Weeds.**—At the New Hampshire Station[1] on an uncultivated plat on which weeds grew luxuriantly, the yield of grain was 17.1 bushels per acre, while on a plat cultivated shallow five times, the yield was 79.1 bushels, and when cultivated deep five times it was 69.7 bushels per acre. The injury due to weeds may be attributed to three causes:

(1) They consume plant food. The plant food removed by the largest possible crop can easily be supplied in fertilizers. As good a crop could not be raised in this way as would be obtained if no fertilizer were applied and the land kept free of weeds. Hence, weeds must do something else.

(2) Weeds shade the ground. They obstruct the sunlight and perhaps keep the soil cooler. The author, however, mulched a plat sixteen days after planting, with sufficient coarse, strawy manure to keep the weeds in subjection, and obtained forty-eight bushels of grain and 5,009 pounds of maize fodder, as compared with forty-six bushels of grain and 4,686 pounds of fodder when cultivated one to two inches deep, and forty-one bushels of grain and 4,224 pounds of fodder when cultivated four inches deep. Hence, weeds must do something else.

1 N. H. Bul. 71, p. 47.

(3) Weeds evaporate water. The demand of the maize plant for water is so great at certain periods of its growth that the possibility of development and yield is fixed by the supply of water available. (280) If this supply of water is in any way reduced by the growth of weeds, the yield of maize must be reduced. Sturtevant observed the difference in practice among the vineyardists in New Jersey. Those on the low lands allow weeds to grow: on the uplands the soil is kept free of weeds. The inference is that the weeds pump the water out of the wet land to the advantage of the grape, which prefers a dry soil.

310. **The Effect of Stirring the Soil** is to break the roots in the area stirred and to make the soil in this area looser, otherwise change its structure and to bring particles of soil into different relations one to another. This allows air, water and roots to enter more freely. The amount of water, the temperature, and probably the salts in solution are affected thereby. (297) King found that cultivating three inches deep made the soil .4 to 1.1° F. cooler than cultivating 1.5 inches deep.[1]

311. **Root Pruning.**—It has been clearly demonstrated that any mutilation of maize roots has an injurious effect. At the Illinois Station[2] pruning three to four times during the ordinary season on all sides six inches from the center of the hill to a depth of four inches reduced the yield of grain from ten to thirty-two per cent, the average decrease for five years being twenty per cent. The greater percentages of decrease were during seasons of least rainfall. Pruning three inches deep one season caused a decrease of five per cent. The Oklahoma Station[3] found during one season no injury from running a knife three inches deep six inches from the hill, or six inches deep twenty-two inches from the hill, but when the knife ran six inches deep six or twelve inches from the hill the yield was much reduced.

1 Wis. Rpt. 1893, p. 190; 1894, p. 283.

2 Ill. Buls. 13, 25, 31.

3 Okla. Bul. 36.

The New York State Station found a decrease in grain of twenty-eight per cent and in stover of twenty per cent during a dry season, pruning three inches deep three to four inches from the hill. During a rainy season pruning in the same manner the second and last time when plants were only ten inches high decreased the yield of grain seventeen per cent and the stover twenty-three per cent.

**Table Showing Results of Deep and Shallow Culture.**

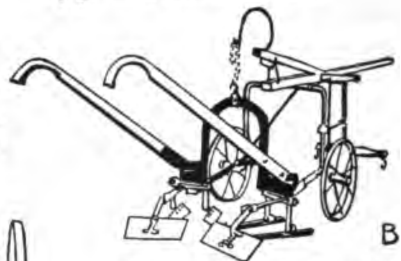
| Station | Total experiments | Favoring shallow | Favoring deep | Inconclusive |
|---|---|---|---|---|
| Alabama | 3 | 3 | .. | .. |
| Georgia | 4 | 1 | 1 | 2 |
| Illinois | 6 | 5 | .. | 1 |
| Indiana | 9 | 7 | 1 | 1 |
| Kansas | 3 | 1 | 2 | .. |
| Maryland | 6 | 3 | 3 | .. |
| Michigan | 1 | 1 | .. | .. |
| Minnesota | 3 | 2 | .. | 1 |
| Mississippi | 4 | 3 | 1 | .. |
| Missouri | 3 | 3 | .. | .. |
| Nebraska | 1 | 1 | .. | .. |
| New Hampshire | 1 | 1 | .. | .. |
| Ohio | 8 | 6 | 2 | .. |
| Oklahoma | 2 | 1 | .. | 1 |
| Pennsylvania | 1 | .. | .. | 1 |
| South Carolina | 2 | .. | .. | 2 |
| South Dakota | 3 | 3 | .. | .. |
| Utah | 5 | 2 | 3 | .. |
| Wisconsin | 4 | 1 | 3 | .. |
| Total | 69 | 44 | 16 | 9 |

312. **Depth of Cultivation.**—While the experiments in root pruning suggest that decided injury would result from deep culture, they do not show what influence stirring the soil might have in counteracting such injuries. Not less than nineteen

stations have made tests of deep and shallow cultivation, as shown in table on preceding page.

Sixty-one tests of deep cultivation at thirteen stations gave an average yield of sixty-five bushels, while fifty-five tests of shallow culture gave seventy-five bushels per acre, a decrease of thirteen per cent due to deep cultivation.[1] Most of the stations have considered one to two inches deep, shallow cultivation, and four or more inches deep, deep cultivation. In some of the trials where deep cultivation was found the best, notably at the Wisconsin Station, deep cultivation was only three inches deep, and in the average of twenty-one trials was only one per cent


A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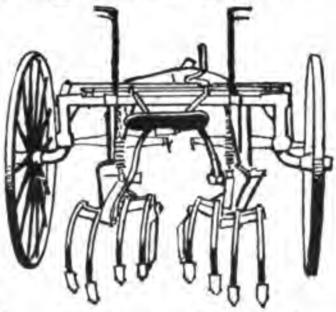
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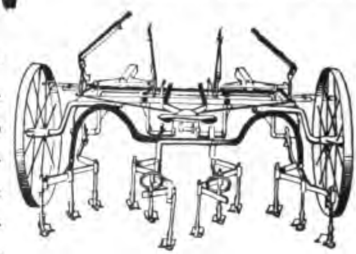

D

Tools for the shallow cultivation of maize. A, one-horse cultivator with three broad shovels in rear, the width and depth being adjustable, requiring the passage twice to cultivate a single row; B, two-horse walking cultivator, with broad knives for complete surface tillage, cultivating a single row at each passage; C, two-horse riding cultivator, shallow cultivation being secured by four, sometimes five, small shovels on each side, the depth being adjusted by means of levers shown above frame; cultivates a single row; D, three-horse riding cultivator for cultivating two rows at one passage.

1 Miss. Bul. 33, p. 63.

greater than when cultivated one and a half inches deep. Studies of root growth of maize made at the Illinois Station indicate that fifty per cent more roots may be cut off at four than at three inches deep. The evidence in favor of shallow cultivation is even more conclusive, therefore, than the table indicates. While the evidence seems to show that the breaking of the roots while the plant is less than six inches high is not so serious as at later periods of growth, and that plowing deep at the first cultivation is not so injurious as at a later date, yet, on the other hand, evidence does not indicate any special benefit from such deep culture in the majority of cases. Doubtless something will depend upon the previous preparation of the seed bed. If the seed bed has not been properly prepared before planting, or if the land has become extremely compact from heavy rains or otherwise, a deep cultivation while the plants are quite small may prove beneficial, but the evidence clearly indicates that in the majority of cases shallow cultivation at all times will give the best results, provided such cultivation is equally effective in eradicating weeds. In practice, shallow cultivation has been found equally effective in destroying weeds, provided the weeds are not allowed to get too large, in which case deeper cultivation sometimes becomes necessary.

313. **Amount of Cultivation.**—The injury from root pruning has generally been greater than injury from deep cultivation. This may be due to the cultivation having injured less roots or to the beneficial influence due to stirring the soil. During five years the Illinois Station[1] cultivated a plat two inches deep and four inches deep, while on an adjacent plat the weeds were removed by scraping the surface with a sharp hoe without breaking the crust of earth. The average yield was, deep, sixty-six bushels; shallow, seventy-two; none, sixty-eight bushels. During two years on one plat where weeds were allowed to grow,

1 Ill. Bul. 31, p. 356.

no maize was obtained. This experiment has been verified by the New Hampshire[1] and Utah[2] Stations.

Plats were also cultivated from three to five times a season in comparison with plats cultivated about three times as much. The averages for five years are as follows:

| | Bushels grain per acre |
|---|---|
| Shallow, ordinary | 70.3 |
| Deep, ordinary | 66.7 |
| Shallow, frequent | 72.8 |
| Deep, frequent | 64.5 |
| Frequent, average | 68.6 |
| Ordinary, average | 68.5 |

Eight other stations have found similar results, while the Michigan Station found that frequent cultivation gave a yield of twenty-five per cent more dry substance than infrequent culture.[3]

No advantage has been found in cultivating maize after the plant is three to four feet high, provided it is free of weeds at that time; and cultivation to prevent subsequent growth of weeds has not materially increased the yield, and when cultivation was deep, has decreased it.

314. **Conservation of Moisture: Influence Due to Stirring the Soil.**—It has been shown that allowing the weeds to grow almost prevents the growth of maize; that when weeds are removed no stirring of the soil gave better yields than deep stirring; while shallow stirring gave better results than either no stirring or deep stirring, while finally stirring two or three times a week gave about the same results as stirring once a week during the

[1] N. H. Bul. 71 (1900), p. 50.

[2] Utah Bul. 66, p. 108.

[3] Okla. Bul. 63 (1898), p. 4. Ga. Bul. 58 (1902), p. 208. Kan. Bul. 64 (1897), p. 233. Ohio Rpt. 1888, p. 87. N. H. Bul. 71 (1900), p. 51. So. Dak. Rpt. 1900 (E. S. R. II: 511). Mich. Bul. 164, p. 90. Wis. Rpt. 1894, p. 282. Md. Bul. 62 (1899), p. 195.

usual period. Aside from its influence in destroying weeds, which appears to be the main purpose of all intercultural tillage, a moderate amount of stirring to a depth which will not seriously injure the roots appears, therefore, to be somewhat beneficial.

If two inches of cut straw are spread upon the surface of the soil, the evaporation of water from the soil will be checked. If the surface of the soil is sheltered from rain, but exposed to the sun, and at the same time stirred to the depth, say, of two inches, the stirred portion rapidly becomes dry, and when in this condition acts as a mulch to the soil below, although not as effectively as does the cut straw. Under the above conditions the author has checked evaporation of water from the soil equal to one-fourth of an inch of rainfall per week.

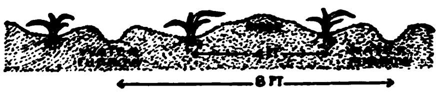
When, however, the soil is exposed to the usual atmospheric conditions of the humid regions, where it rains one day in three, it becomes a question whether the evaporation from the lower soil is checked more than that from the stirred portion is increased. The author has concluded from pot experiments conducted during three seasons that for humid regions during ordinary weather these two factors were nearly equal, although during rainy weather the evaporation may be increased and during periods of severe drouth it may be decreased by constant surface stirring of the soil, both of which may be desirable. The average evaporation in inches of rainfall from two pots treated as indicated below was determined for eighty-six days during the months of June, July, August and September at the Pennsylvania Station:

**Evaporation in Inches of Rainfall During Eighty-Six Days.**

| | |
|---|---|
| Water | 19.8 |
| Bare soil not cultivated | 16.0 |
| Bare soil cultivated | 16.7 |
| One maize plant, soil not cultivated | 19.3 |
| One maize plant, soil cultivated | 18.8 |
| One maize plant, soil mulched with cut straw | 10.6 |
| Oats followed by oat stubble | 27.7 |

In these experiments only the loss of water from evaporation was determined. The looser soil will absorb more of the rainfall and thus lessen the amount that runs off the surface. This is especially true of compact clay soil and those having considerable slope. Generally, but not always, the looser soil will hold the most water and retard its falling beyond the reach of the roots. Since the trials which have been made indicate that surface cultivation is better than no stirring, and since occasional stirring has given as good results as frequent stirring, the inference is that so far as the conservation of moisture is concerned the most important effect of stirring the soil is to enable it to absorb and hold the rainfall.

315. **Hilling and Bedding.**—Some throwing of the earth towards the row is often necessary in order to cover and destroy weeds. On all well-drained soils, hilling does not give any better results than level culture, and when, in order to hill, deep cultivation is practiced, then injury results. (312) On the poorly drained bottom lands of the Southern States bedding is practiced to give surface drainage. The Mississippi Station[1] recommends that the beds be made eight feet wide or wide enough for two rows with water furrows in the alternate rows.



Method of bedding for low wet land. (After Hartley.)

[1] Miss. Bul. 33.

# XV.

## MAIZE.

### WEEDS, FUNGOUS DISEASES AND INSECT ENEMIES.

316. **Weeds.**—Maize differs from the other cereals in that the grain as it goes to market does not contain weed seeds, nor is there any danger of adding such seeds to the soil when the maize is planted. There are, therefore, no distinctive weeds of the maize crop, but weeds that chance to infest the soil may occur in the maize field. Fields are not infrequently cultivated in order that the cultivation incident to the maize may partially or wholly eradicate existing weeds. This, in fact, is one of the purposes of a systematic rotation of crops. Besides the injury that all weeds do, some are more troublesome than others, either through their tenacity, their immediate injury to the young maize plant, or through the inconvenience which their presence involves. Among the more troublesome weeds of the maize field may be mentioned:

(1) Foxtail (*Chamoeraphis*).
(2) Bindweed (*Convolvulus*).
(3) Cocklebur (*Xanthium canadense* Mill., and *X. spinosum* L.).
(4) Spanish Needles (*Bidens bipinnata* L., *B. connata* Muhl., and *B. frondosa* L.).

317. FOXTAIL.—There are two species of foxtail; one known as Pigeon grass (*Chamoeraphis glauca* (L.) Kuntze), and the other known as Bottle grass (*Chamoeraphis viridis* (L.) Porter). So far as actually reducing the yield of grain is concerned, these foxtails are probably the worst weeds that infest the maize fields. They are annuals, varying from a few inches to two feet or more in height, with dense spiked heads, yellow in Pigeon grass and green in Bottle grass. The heads are less dense and the bristles longer in the latter. Their abundance of seed, produced almost under any environment, which is evidently stored in the soil for considerable periods, makes it almost, if not quite impossible, to eradicate it permanently.

318. BINDWEED.—There are a number of species belonging to the Morning Glory family which may infest cultivated fields; the most serious are the field

bindweed (*Convolvulus arvensis* L.), imported, and the hedge bindweed or morning glory (*Convolvulus sepium* (L.) Willd.), native. Both are perennial vines, with extensive underground stems, which make them practically impossible to eradicate. They may be greatly reduced by thorough cultivation. Where they are a serious pest, it is desirable to cultivate the field two years in maize, in order to reduce their injury to succeeding grain and grass crops. Good results have been obtained by using sorghum or rye as a smother crop. They do their chief injury by winding themselves about the cultivated plants. When a badly infested field is to be planted to maize, it is desirable to delay plowing until the weather is favorable for a rapid growth of maize. By this time the bindweeds will have started in the unplowed land. By plowing and immediately planting, the maize will get well started before the bindweeds have recovered from the plowing. The land should be kept harrowed, so as to prevent, as far as possible, the growth of other weeds, until both maize and bindweeds have a good start. If the bindweeds are now cut off with a hoe, and the land thereafter kept cultivated in the usual manner, no further serious inconvenience will be experienced from the bindweeds.

319. Cocklebur is also a branching annual, belonging to the Aster and Daisy family. It grows from one to two feet high, and is especially distinguished for its large spiny burs, which are so serious an inconvenience by clinging to the bodies of our domestic animals. Each bur contains two seeds, only one of which grows the first year, the other remaining dormant until the second year, unless the plant of the first seed has been destroyed, when, as shown by McCluer, the second seed may germinate. The plants usually grow in such limited numbers that those which escape destruction through ordinary methods of cultivation may be pulled by hand.

320. Spanish Needles, Stick-Tights, Beggar's Ticks.—These are branched annuals belonging to the Aster and Daisy family (*Compositae*), growing two to four feet high, with brown, thin, flat seeds, two to four downwardly barbed awns. These weeds do their principal damage by the seeds adhering to animals and clothing. Reasonably careful cultivation will destroy them.

321. **Fungous Diseases.**—The more important fungi which attack the growing maize plant are as follows:

(1) Maize smut (*Ustilago zeae* (Beckm.) Ung.).
(2) The bacterial disease of dent maize (*Bacillus cloacae* Jordan).
(3) The bacterial or wilt disease of sweet maize (*Pseudomonas stewarti*).
(4) Maize rust (*Puccinia sorghi* Schw.).
(5) The leaf blight fungus (*Helminthosporium graminum* Rab.).

The maize smut is the only disease that has assumed any widespread economic importance.

322. Maize Smut differs from the smut of the other cereals in its mode and source of infection, making its appearance upon any part of the plant above ground; although the ears and tassels are the portions chiefly infected. Formerly it was thought that infection was largely by means of smutty seeds. It is now pretty well

agreed that the principal and perhaps the only source of infection is from the flying conidia produced by the germination on the ground of the myriad spores of the smut boil. Warmth, moisture and soluble food material are very essential to the germination of the spores and the spread of the disease. Naturally, therefore, as the season of active growth progresses the conditions favorable to spore germination increase and the number of pustules is increased as the foliage, tassels and silk increase to afford a suitable matrix for the conidia. The abundance of silk and the great amount of nourishment in the grains explain the enormous development of the smut boils, which often attain the size of a man's head. The infection is purely local; the disease does not spread, as is shown by the appearance of the smut boils at the point of infection two to three weeks after the conidia have made their entrance into the host. Thus, it is seen that infection may take place at any time in the growing season, and the longer the season of growth, the greater the infection is likely to be. It is reported that sweet maize is more susceptible to the disease than the ordinary field maize; estimates on the percentage of infection of the latter have been variously stated at from five-tenths to twenty-six per cent. It therefore follows that the extent of infection depends considerably upon five factors: (1) seasonal conditions, a rainy season tending to keep much of the conidia washed out of the air, while much dry weather is fatal to the germinative powers; (2) the thickness of planting, the moisture held by the plants being increased as the foliage is multiplied; (3) the presence of decayed vegetable matter; (4) manure, which may be infested with spores; (5) the degree of maturity of the different parts of the plant. The only practical method of prevention, so far as known, is to gather all smut pustules as they appear, care being taken to prevent scattering the black powder (spores), two or three times in the growing season and destroy them by burning or placing in boiling water. Great care should be taken, also, in seeing that, as far as possible, the manure for the maize field is free from spores. Experiments have shown that the hot water treatment used for smut of oats and wheat is of no avail in combating maize smut; this is explained by the fact that inoculation of the host comes not from the seed but from the flying conidia which alight upon the growing plant. Maize smut has been fed to cattle in numerous instances in large quantities for a considerable period of time without apparent injury.[1]

Maize smut boil.

323. Bacterial Disease.—There has been observed in Illinois and other North Central States a bacterial disease of maize, which not only does considerable damage to maize in some localities, but it is supposed that the germ which causes the disease in maize is able to cause a sudden and fatal disease in cattle,

[1] For detailed study of maize smut, see Ind. Rpt. 1899 (12), pp. 84-135; also Farmers' Bul. 69; Kan. Bul. 62; Ohio Bul. 78.

called the corn-stalk disease. The first indication of the disease is the dwarfed condition of the young plant. This commonly occurs in spots of various sizes, and is found in rich places, rather than in those of poorer quality. The young diseased plants, besides being smaller than the healthy ones, are uniformly yellowish in color, the lowest leaves showing worst. Affected plants are easily pulled from the ground on account of the death of the lower roots. The inner tissue of the lower part of the stalk has a uniform dark color, while on the surface there are brownish corroded spots. After midsummer the leaf-sheaths become spotted with various sized patches of a watery-brown, half rotten in appearance, which are most conspicuous from the inner surface. The ears are at least occasionally affected. Internally, in the worst stage, the whole ear is reduced to a moist state of corruption. Very often these ears subsequently become mouldy, penetrated through and through by a close, very white, felt-like fungus. These mouldy ears are, in certain seasons, very numerous, and are readily recognized by the husker. No remedy is known. There appears to be in a considerable number of cases more injury on land which has been planted with maize the preceding year.

324. Bacterial Disease of Sweet Maize.—Plants affected by this disease wilt and dry up very much like plants suffering from lack of moisture, except that there is little or no rolling of the leaves. Diseased plants are intermingled with healthy ones. The woody strands of the plant are filled with a multitude of short, yellow bacilli, which, when the stem is cut across, exude as a yellow viscid substance. The disease is confined to sweet maize, and is most destructive to early varieties. It is disseminated chiefly by means of the germs which cling to the seed. No remedy is known. The principal measures of prevention are selection of seed and the planting of resistant varieties.[1]

Uredo stage or red rust on maize leaf. Disease produced by inoculation by Kellerman

325. Maize Rust is found wherever maize is grown, but principally in regions of considerable rainfall. The rust does not differ materially in appearance from rusts of other grasses, particularly *Puccinia graminis* of wheat and oats; the surface of the affected leaf and sheath displays small oblong or elliptical spots, which contain reddish-brown spores. Kellerman has shown that only the uredo and teleuto stages may be included in the life cycle, although Arthur has identified the aecidial stage on oxalis.[2] It passes the winter in the teleuto stage. Though fungicides are effective, the rust is of such little economic importance as not to warrant treatment. Pammel reports decreased yields of sweet maize due to the rust. The rust also occurs on sorghum and teosinte.

326. The Leaf Blight Fungus has been reported in maize, causing extended or elliptical brown (dead) areas in the leaf blades, not distinguishable by the unaided eye. The disease is of little economic importance.

[1] N. Y. (Geneva) Bul. 130.

[2] Botanical Gazette, July, 1904.

327. **Insect Enemies.**—Two hundred and fourteen species of insects are known to be more or less injurious to the maize plant. Insect injuries are more common and more extensive in the Southern States than in the Northern States. Except, however, for those insects which attack the young plant and make replanting necessary, destruction of the crop is seldom complete. The larger number of the injuries to maize occur after plowing up grass land of long standing, or are due to continuous culture of maize upon the same land several years in succession. Some of the insects also pass a portion of their life on or can use weedy plants for food. Generally, therefore, the most effective remedies against insect attacks are short and systematic rotations, accompanied by clean culture of the maize field and the surrounding territory. Where the land is neither in grass nor maize more than two years in succession the attacks of insects are comparatively limited; except, perhaps, in the case of certain migratory insects, such as the chinch bug, locusts and army worms, whose increase in numbers has been brought about by special conditions. The insects of most economical importance to growing maize are as follows:

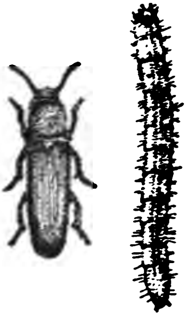
(1) Wireworms (*Elateridae*).
(2) Cutworms (*Noctuidae*).
(3) White grubs (*Lachnosterna* spp.)
(4) Corn root worms (*Diabrotica longicornis* Say and *D. 12-punctata* Oliv.).
(5) Corn root web-worms (*Crambus* spp.).
(6) Corn root louse (*Aphis maidi-radicis* Forbes).
(7) Corn bill bugs (*Sphenophorus* spp.)
(8) Corn ear-worm (*Heliothis armiger* Hubn.).
(9) Stalk borers (*Noctuidae* and *Pyralidae*).
(10) Chinch bug (*Blissus leucopterus* Say) (151).

The insects most injurious to the stored grain are the same as those affecting stored wheat. (156)

328. WIREWORMS are the larvae of the large family of click beetles or "Jumping Jacks," eight species of which are known to be injurious to maize.[1] The worms vary in length from one-half to one and one-quarter inches, have a hard,

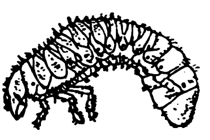
[1] Ill. Bul. 44, p. 224.

smooth, shining surface, varying in color from yellowish to reddish-brown. They pupate in July and August, and transform to beetles three or four weeks later. The beetles remain in the soil and emerge the following spring. Eggs are then laid in the earth in grass land, where they soon hatch, the larvae requiring at least two years to become fully grown. The larvae are very destructive by attacking the seed in the ground before it is sprouted, and also by eating and boring the roots and stems of the young growing plant. The injury is likely to be greater the second year, after sod has been broken up. All cereal crops may be attacked. No successful remedy has yet been proposed, although fall plowing is believed to be helpful. When replanting injured maize it is customary to put the new seed between the attacked rows, which are left to stand as a food supply until cultivation becomes necessary.



Beetle and larva of wireworm, enlarged two times. (After Forbes.)

329. CUTWORMS.—There are at least fourteen distinct species of moths whose larvae have the cutworm habit. The life history of the different species, of course, varies somewhat, but in general their injuries and treatment are substantially the same. The moths lay their eggs upon the leaves of grasses in meadows and pastures and the larvae feed upon the growing vegetation. The fully grown cutworm is one and one-quarter inches to two inches long and varies in color with the species from dull brown to gray or green and is variously marked with longitudinal or oblique stripes and dashes and dots. The moths lay their eggs during midsummer and partially grown larvae pass the winter in the ground. Thus when grass lands, especially of long standing, are plowed up and planted to maize, the cutworms, being deprived of other vegetation, attack the young maize plants when only a few inches high, cutting them off just above the ground. The larvae pupate during late spring and summer, some species on the fortieth parallel as early as the fourth week in May, thus permitting late planted maize to escape their attacks. Late fall plowing is measurably effective by disturbing and exposing the worms and by destroying the food on which they would feed during spring. They may also be poisoned by a mixture of wheat bran, forty pounds; molasses, two quarts; paris green, one pound, mixed with enough water to moisten. A tablespoon of this mixture placed near each hill will attract the cutworms and prove fatal.



White grub, about natural size. (After Forbes.)

330. WHITE GRUBS.—White grubs are the larvae of May beetles or June bugs, of which a number of species are known to attack maize. The beetles lay their eggs mostly during June in the earth, commonly in grass lands but not infrequently in maize land also. The eggs hatch in ten to eighteen days and the grubs are supposed to live over two full years, the complete life cycle being three years. White grubs do their injury by feeding upon the roots of the young maize plant, sometimes causing immediate destruction,

in other cases causing prolonged and a more or less partial injury. These grubs are also extremely destructive to grass lands, in some cases causing complete destruction of the sod. The adult beetles also frequently cause considerable injury by feeding upon the leaves of deciduous trees. No thoroughly satisfactory remedy has yet been proposed for this insect.

331. CORN ROOT WORMS.—There are two species: the western corn root worm and the southern corn root worm. The larva of the western corn root worm is two-fifths of an inch long, about as large as a pin, body somewhat cylindrical, colorless, except the head, top of the first segment and a little patch on the last segment of the body, which are yellowish-brown. The injury is done by the larva, chiefly during July and August, by beginning in the tip of the maize root and working towards the plant, devouring the inner portion of the root as it goes. It pupates in the earth among or near the roots of maize. The pupae emerge in August or September as grass-green beetles about one-fifth of an inch long and half as wide. The beetles feed upon the pollen, silks and in some cases upon the soft grains at the top of the ear, but usually the injury done by the beetle is trivial. The beetle lays clusters of five to a dozen dirty-white eggs one-fortieth of an inch long in the ground, one inch to six inches deep, about the maize plant during October and November. Only the eggs survive the winter, hatching in May and June. The southern corn root worm is distinguished by the beetle being larger and having three transverse rows of four black spots on the wing covers. Since the larvae of these two species have no other host plant and since the eggs are usually laid about the hills of maize plants, a rotation of crops furnishes a simple and effective remedy for these insects. It is likewise destructive only in those sections where maize is cultivated on the same land several years in succession.

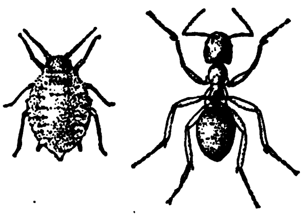
Western corn root worm, enlarged three times. (After Forbes.)

332. CORN ROOT WEB-WORMS.—They are the larvae of at least five species of moths which lay their eggs among the grass in the summer, the larvae passing the winter in a half-grown condition. They attack the young maize plant just above ground, and when not at work they remain in a silken web just underneath the ground at the base of the plant. The fully grown larva is about half an inch long, somewhat hairy, varying in color from brown to dirty white. They pupate about June first, on the fortieth parallel. They may also attack oats.[1] Their injuries to maize may be avoided by late planting. Ordinarily, injury is to be expected only where maize follows grass; the longer the land has been in grass the greater the danger.

333. CORN ROOT LOUSE.—All plant lice are enormously prolific. During the summer the wingless females of the corn root louse reproduce continuously, without the intervention of the males, living young which, when a few days old, also begin to multiply. Winged females appear from time to time and establish new colonies, while in the fall large numbers of individuals of both sexes appear. Generally the last brood lays eggs from which the spring brood is produced. Ants apparently

1 Ohio Bul. 68, p. 48.

protect and care for the plant-lice in return for their secretions which they consume. They are held in check by carnivorous and parasitic insects. The corn root louse does its greatest injury to the young maize plant during May and June, causing the plant to wither and die by sucking its juices. Usually these attacks are in spots throughout the field and are likely to be most injurious during unfavorable weather conditions. The injury done by these insects is variable and fitful, owing, doubtless, to their great prolificacy and the enemies which keep them in check, so that remedial measures are usually of slight avail. The corn plant louse (*Aphis maidis*) attacks the plant above ground, but it appears to be less injurious than the corn root louse, whose attacks are confined to the roots.



Corn root louse on the left and its caretaker, the ant, on the right, both enlarged. (After Forbes.)

334. Corn Bill Bugs.—Several species of bill bugs are known to be injurious to maize. The adults are black beetles one-fourth to three-fourths inch long, which do their damage by puncturing the stalks and the young leaves of maize as they are unfolding. Eggs are usually laid during the spring and summer and reach the pupal stage in about one month. In some species the larvae live in the interior of the stalk, bulb or roots of small grain or timothy, and in other cases in the maize plant itself. They pass the winter in the adult form. The damage is generally comparatively slight. There is no specific remedy.

335. Corn Ear-Worm.—The larva, one and one-half inches long, varies in color from pale green to dark brown, is marked with longitudinal stripes of the same color, with eight round shining black spots on each segment of the body from which arise short hairs; the head and neck are brown. It is two to seven-brooded, depending upon the latitude. The last brood passes the winter in the pupal stage, emerging as a moth in the spring. In the Northern States the most destructive brood lays its eggs in the silk when the ears are young, and the larvae feed upon the grains at the tip of the ear, often doing great damage, not alone on account of the grain actually eaten, but also through subsequent decay by access of moisture and through destruction due to other insects. In the Southern States the earlier broods are also destructive by feeding upon the leaves and stalks. This insect is injurious to cotton by feeding upon the bolls; hence is known as the boll worm. Disturbance of the pupa by late fall plowing or early spring plowing appears to be of some value, although no remedy has been found which is entirely efficient.

336. Stalk Borers.—There are at least three species of insects which injure maize by boring in the stem, although they are often equally injurious to other plants, including weeds; namely, the stalk borer (*Gortyna nitela* Guen.), the smaller stalk borer (*Pempelia lignosella* Zeller) and the larger stalk borer (*Diatraea saccharalis* Fab.).[1] The most serious injury is usually done by the latter, which in the South Atlantic States occasionally amounts to twenty-five to fifty per cent of the crop.

[1] U. S. Dept. of Agr., Div. Ent. Cir. 16, 2d Ser.

The larva is three-fourths inch long, white and marked with dark brown spots. It bores the stalks of young maize, seriously injuring it, and later bores into older stems, working down into the tap root, and passes the winter in the pupal stage in a channel about the surface of the ground or a little below. The moth issues in the spring, soon to lay eggs near the base of the leaves. It also attacks sugar cane and sorghum, as well as gama or sesame grass (*Tripsacum dactyloides*), and consequently is more likely to be a dangerous pest near swampy lands, where this grass grows. Clean culture and systematic rotation of crops is a fairly effective remedy.

## OTHER ENEMIES.

337. THE CROW.—In many sections, especially where maize is planted near clumps of timber, the American crow (*Corvus Americanus* And.) pulls up and eats the young plant, often causing considerable damage. Most of the preventive measures recommended have for their basis methods of frightening the crows away until the plants are large enough to resist their attacks. Among these measures are the simple scarecrow, trapping the birds alive and keeping them tied in the field, and poisoning a few with maize grain soaked in strychnine as a warning. Coating the seed slightly with coal tar is sometimes quite effective. This may be done by dipping a wooden paddle into the hot liquid and then stirring it rapidly among the maize grains. There is some danger of decreasing the germination. It is generally conceded that except for this annual depredation the crow is useful to agriculture as a destroyer of insect pests.

338. THE AMERICAN BLACKBIRD (*Agelaius phoeniceus* Linn.) occasionally does somewhat serious damage by feeding upon grain while it is still soft.

339. THE STRIPED PRAIRIE SQUIRREL (*Spermophilus 13-lineatus*), especially in sections from Illinois westward, frequently makes replanting necessary by digging up and consuming the sprouting grain. Gillette has shown that injurious insects constitute a large proportion of its food. It is believed that these squirrels are not only beneficial to meadows and pastures, but to subsequent maize crops, because of their destruction of cutworms, wireworms, web-worms and similar insects.

# XVI.

## MAIZE.

### I. HARVESTING AND PRESERVATION.

340. **Harvesting.**—Although there has been considerable progress in the harvesting of maize, no such profound changes have been made as those noted in the harvesting of the small grains. The larger part of the crop is still husked by hand from the standing plant and cattle allowed to roam over the husked fields to pick up neglected ears and nubbins, and to feed upon the leaves and husks. Attempts to husk the standing maize by machinery have not met with success.

Maize harvester and shocker; shock is built upon the platform by the machine, after which it is raised by the derrick and placed upon the ground, out of the way of the machine on its next round.

341. **Storing.**—After being husked, the ears of maize are stored in ventilated (slatted) bins, called cribs, in order that the excess of moisture may evaporate before the grain is shelled. (233) While on the ear, the grain is not readily injured for feeding purposes by exposure to atmospheric conditions, but when shelled is subject to heating and molding, if not thoroughly air-dry. A difference of two per cent in moisture content may materially influence the keeping quality of the shelled grain.

When maize is stored in the ear, it is particularly subject to attacks from rats and mice because of the facility with which these vermin may pass between the ears. Special precautions

should be taken to reduce their ravages to a minimum by raising the bottom of the crib from the ground, thus reducing their hiding places as well as giving access to cats and dogs.

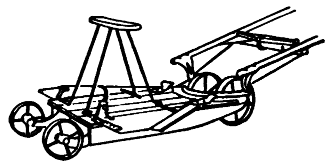
342. **Maize Fodder.**—In the North Atlantic and Southern States, and in portions of the North Central States, most of the maize is cut and put into shocks or into the silo. This cutting may be, and for the most part still is, done by means of a corn knife, although the corn cutter and the corn harvester are both largely used, the latter especially where maize is cut for the silo. A machine has recently been invented which cuts and shocks the maize at one operation, but its use has not yet become general.

Husking rolls of maize husker and shredder.

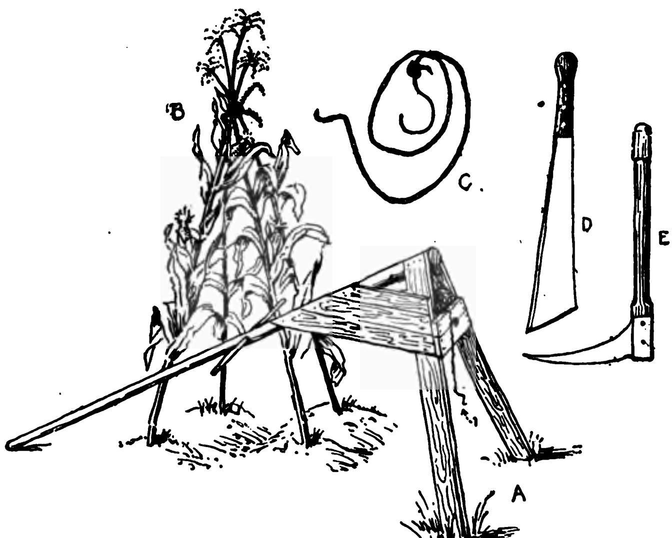
From 5 x 7, or thirty-five hills, to 12 x 12, or 144 hills, are placed in a single shock. The lesser quantity is common in the North Atlantic States, where, according to the Connecticut Station, it is more difficult to preserve flint stover, while ten hills square, or 324 shocks per acre, is the common amount in the North Central States. A common method is to tie four hills together without cutting them off and then to shock the rest of the plants around these; while in other cases a wooden horse is used as a temporary support. When the shock is completed, a light rope with a hook on one end is used to draw the top of the shock together, when it is tied with twine or in some

Maize harvester. Cuts and binds plants into bundles, which may afterwards be put into shocks; also very useful in harvesting maize for silage.

cases with a stalk of maize. After the plant has become cured, which usually takes about a month, the shocks are generally husked by hand in the field, the stover tied into bundles; the four hills which had been used for supports are cut off and bound with the rest of the stover. These bundles are again shocked and the shocks tied, or the stover is hauled directly to the barn and stored. It is necessary to choose suitable weather conditions, since if the plants are too dry, the leaves will fall off and be lost, while extremely wet weather would be equally injurious.



Maize cutter. Blade on each side severs stalks while men riding upon the machine gather them together and shock them. Two rows may be cut at one time, or, raising one blade, only one row.




Methods of cutting maize by hand. A, wooden horse used to support stalks while shock is being built; B, four hills used as support for shock when wooden horse is not used; C, rope with hook for drawing shock together prior to tying with string shown at A1; D, maize knife used in North Central States; E, maize knife used in North Atlantic States

The husker and shredder, which has now come into considerable use, eliminates the labor of husking and puts the stover in a condition to be easily handled. It may be stored in the barn or even put into a stack, but in order to keep, the stover must be thoroughly dry at the time of husking. Itinerant machines go from farm to farm in many localities husking either by the day or at a fixed price per bushel. Threshing machines have sometimes been used for threshing maize fodder. The chief objection to the threshing machine is that it shells the grain, which at that time usually contains too much moisture to be stored in this manner.

Where beef cattle are fattened, the maize fodder, generally called "shocked corn," is fed without being husked, thus supplying concentrated food and roughage at the same time.

343. **Topping.**—Removing that part of the culm or stalk above the ears instead of cutting and shocking the whole plant has been somewhat widely practiced in both the North and South Atlantic States.

The Pennsylvania Station[1] found that by topping, 1,050 pounds of stover were obtained at a loss of 540 pounds of ear maize, as compared with allowing the maize to ripen and merely gathering ears. Mississippi Station,[2] as the result of three years' trials, found a net loss in feeding value of more than twenty per cent. Seven other stations show an average loss of thirteen bushels per acre, which was "more than the feeding value of the 'fodder' secured." At the Arkansas Station,[3] neither topping nor pulling reduced the yield of grain so much as cutting and shocking the whole plant when ears were just past the roasting-ear stage, as shown in the following table:

[1] Penn. Rpt. 1891, pp. 58-60.

[2] Miss. Bul. 33 (1895), p. 63.

[3] Ark. Bul. 24 (1893), p. 121.

**Effect of Method of Harvesting Maize.**

| Method of treatment | Pounds per acre | Pounds loss per acre | Bushels per acre |
|---|---|---|---|
| Left natural . . . . . . . | 1,241 | .... | 22 1-7 |
| Topped above ear . . . . . . | 1,224 | 17 | 21 5-7 |
| Leaves stripped . . . . . . . | 1,102 | 138 | 19 5-7 |
| Stalks cut and shocked . . . . | 1,075 | 166 | 19 1-5 |

344. **Pulling.**—Throughout the Southern States there is a tendency for the leaves of maize to dry up before the ears are mature, and it has been the custom to strip the leaves from the culms while they are still green and the ears immature.

"Fodder pulling is effected according to latitude and season from the first of August to the middle or even the last of September. When the operator's hands are full of blades and he can hold no more, the quantity is termed a 'hand,' and is bound rapidly with a twist and hung on a broken stalk to cure. On gathering a day or so later, from three to four hands form a 'bundle,' which is, also, bound with a few twisted blades. The bundle weighs from one and three-fourths to two pounds and forms the staple 'roughage' of southern draft stock." [1]

At least eight stations in the Southern States have investigated the influence of this practice on the yield of grain, and in general report a decrease of from ten to twenty per cent. The earlier the work was done, the greater the loss. Redding[2] concludes that "pulling fodder" is only expedient under the most favorable circumstances, but where it is resolved to do so, the best practice is to strip the blades, from and including the ear-blade, downward, at about the usual time of pulling, and in a week or ten days to cut off stalks above the ear. Besides adding largely to yield of stover, it is believed to be more expeditious.

The Florida Station[3] reports that "pulling fodder" has the effect of loosening the husks on the ear before the grains become hard, thus promoting the ravages of the weevil.

[1] The Book of Corn, p. 169.

[2] Ga. Bul. 23 (1893), pp. 81-82.

[3] Fla. Bul. 16 (1892), p. 8.

**345. Silage.**—Probably the most important change that has been made in the handling of the maize plant in the last quarter of a century is the practice of putting the unripened plant cut into small pieces by a feed cutter into a receptacle with air-tight sides and bottom, called a silo. The essential value of this process, aside from economical farm management, lies in the greater palatability of silage as compared with maize fodder. Experiments show the digestibility of silage and maize fodder to be about equal when all other conditions except method of preserving remain the same. A large number of American feeding experiments, mostly with milch cows, show, in general, about equal food value for amount of dry matter consumed, but that ordinarily there is less waste in the consumption of silage, thus adding to the total returns per acre, and that a rather higher rate of feeding can be maintained with silage, thus adding to the daily production of butter fat.

**346. The Silo.**—A silo should have air-tight bottom and sides and should be constructed in such a manner and of such materials as to be durable, protect the silage from freezing, and afford ventilation. Its sides should be perpendicular, rigid, with inner surface smooth. The efficiency of the silo will depend, also, upon its size and shape. The more compact the silage, the better it keeps. The greater its diameter and the more nearly circular the silo, the less the resistance of the sides to packing. The deeper the silo, the more compact the silage, and the less the surface exposure in proportion to the whole mass. A silo should never be less than twenty-four feet deep, thirty feet is very much better, and forty feet is desirable where practicable and the capacity desired

A modern stave silo.

warrants it. The surface area of the silo should be such that the silage will be fed rapidly enough to prevent decay. It should never be more than ten square feet per cow, five is better; while seven and a half gives good results.

The riper the silage, the less weight the silo will hold. The higher the silo and the greater the diameter, the more weight the silo will hold. The weight and keeping quality will depend also upon the manner of filling. The material should be evenly distributed and the silage next the sides of the silo thoroughly packed by tramping in order to overcome resistance offered by the sides. The more slowly the silo is filled, the more it will hold. A silo sixteen feet in diameter and thirty feet high will hold, when continuously filled with suitably ripened maize, about thirty-three and a third pounds of silage per cubic foot, or about 100 tons of silage. A cubic foot of such silage is a standard daily ration for a cow in milk. The capacity of the silo required may be calculated in cubic feet by multiplying the number of animals to be fed by the days of feeding desired. Twelve tons of suitably ripened maize per acre is a good yield; eight to ten tons per acre is a safer estimate when calculating the land to be planted in order to fill the silo.

347. **Losses in the Silo.**—Babcock and Russell[1] have shown that the changes which take place in the silage are not wholly due to bacteria, but partly, at least, to the respiratory activity of the yet living protoplasm of the plant tissue. The loss due to respiratory activity was shown to amount to about one per cent of the total weight of the silage, and was due to the carbonic acid ($CO_2$) gas evolved. King has shown that the unavoidable losses may amount to from two to four per cent.[2] These are the losses in feeding value which cannot be prevented with a silo of the very best construction, filled in the best possible manner. The losses not due to respiratory activity are due to

[1] Wis. Rpt. 1901, pp. 177-184.

[2] Wis. Bul. 83 (1900), p. 64.

fermentative processes. What the losses are in general practice cannot be accurately stated. Different stations have frequently reported losses of twenty per cent. It is probable that, with the proper construction and filling of the silo, and beginning to feed as soon as filled, the loss will not exceed ten to twelve per cent.

348. **Loss of Maize Fodder by Curing.**—Experiments at the Wisconsin, Vermont[1] and Pennsylvania[2] Stations show a loss of nineteen to twenty-one per cent of the dry matter of maize fodder from field curing. Maize fodder cut when nearly ripe lost about five per cent more than fodder cut when maize was in the roasting-ear stage, evidently due to the large amount of soluble carbohydrates in the former. (351) The loss, when stored in the barn October 29th, was one per cent greater than when allowed to stand in the field until December 18th. Ears cured upon the stalk with as little loss of dry matter (eight to ten per cent) as if picked and dried, but when put in the silo the loss of dry matter in grain was considerably greater. While not economical on account of labor involved, the loss of dry matter could apparently be reduced somewhat by husking ears and placing only the remaining portion in the silo. The losses of the maize plant, both in field curing and ensiling, are largely in the carbohydrates other than fiber.

349. **Time of Harvesting** will depend upon whether the maize is grown for ears alone; for both ears and stover or fodder; or whether for silage. When grown for the ears alone, the plant is not only allowed to ripen, but the ears allowed to remain on the standing stalks until they have become dry enough to be placed in storage, which usually requires about a month after maize is ripe, or after the first killing frost. When stover is to be harvested, it is customary and desirable to allow

1 Vt. Rpt. 1894, p. 171.

2 Penn. Rpt. 1892, p. 43.

the plant to become as ripe as is possible without the leaves falling off before or during the operation of shocking. The ears should be all, or nearly all, dented or glazed, the husks dry, and the leaves from one-third to one-half green. When cut for silage, it is necessary to cut a little greener in order that the mass may pack and sufficiently exclude the air. This condition is reached when many, but not all, the ears have become dented, a portion of the husks dry, and the bottom three or four leaves dry, with the rest still green. On the other hand, up to this stage of maturity, the greener the maize the greater the loss in the silo.

There are six advantages in allowing the plant when intended for silage to arrive at the stage of maturity indicated: (1) greater yield of water-free substance; (2) less weight to handle; (3) less loss in silo; (4) superior composition; (5) greater digestibility; (6) greater palatability; resulting in a greater feeding value per acre at less cost. The following table shows the influence of maturity upon weight of fresh and dry substance and loss in the silo:

| Date | Gr. matter per acre lb. | Dry matter | | Dry matter in silage; loss per acre lb. | Condition of maize |
|---|---|---|---|---|---|
| | | Per acre lb. | Per cent gr. fod. | | |
| Aug. 10 | 19,200 | 2,672 | 13.1 | 752 | In full tassel |
| Aug. 16 | 20,800 | 3,144 | 15.1 | 502 | Maize in silk |
| Aug. 22 | 21,840 | 3,712 | 17.4 | 305 | Grains fully formed |
| Aug. 28 | 19,200 | 3,744 | 19.5 | 288 | Grains in milk |
| Sept. 3 | 16,960 | 3,824 | 22.5 | 195 | Grains still in milk |
| Sept. 9 | 16,400 | 4,168 | 25.3 | 188 | Grains past milk |
| Sept. 14 | 14,720 | 4,536 | 30.8 | 125 | Maize glazed |

350. **Influence of Maturity Upon Yield.**—There is no relation between the apparent size of the maize plant, as, for example, height, and the weight of dry matter. When the plant is in full

tassel it has reached from one-third to one-half its development, measured in weight of water-free substance. When the plant has reached the roasting-ear stage, three-fourths to four-fifths of the dry matter has developed, and when in condition to be put into the silo, from three-fourths to nine-tenths of its dry matter has developed.[1]

Neither is there any relation between rate of growth in height and the development of water-free substance. The greatest rate of growth in height precedes that of the development of dry matter. The total yield of grain increases up to full maturity. The yield of the whole plant has in some instances been found to decrease slightly in weight of water-free substance during the last one or two weeks, doubtless due to loss of leaves. The plant, exclusive of the ear, may decrease materially from translocation of material to the grain. The Iowa Station[2] found a decrease of dry matter in the plant exclusive of the ear to be seventeen per cent of dry matter from the time ears were mostly dented, but leaves and husks all green, until the plant was entirely ripe, requiring a period of three weeks. The circumstances surrounding the experiment lead to the inference that this loss represents a translocation of material to grain, although it may have been due in part to loss of material through dropping of leaves or otherwise.

351. **Influence of Maturity Upon Composition.**—In those grasses and other fodder plants in which the proportion of seed to whole plant is small and the seeds are of low digestibility a deterioration in the plant as a food for domestic animals begins before the plant reaches full maturity, both from a translocation of the material to the seeds and the loss of leaves and other finer parts. Analyses under these circumstances usually show an increased percentage of crude fiber and a decreased percentage of protein. When fed to domestic animals, the riper the product is, the less

[1] Ill. Bul. 31, p. 361; Mich. Bul. 154, p. 283; Cornell Bul. 4, p. 52.

[2] Iowa Bul. 21, p. 778.

palatable and the less digestible it is. In the case of the maize plant, however, it has been found that not only does the total amount of dry matter increase, but the quality of the product increases up to or nearly up to the stage of complete maturity. There is an opportunity for the maize plant to lose its leaves if entire maturity is allowed, the extent of which depends upon weather conditions. On the other hand, the increase in the percentage of starch and of soluble carbohydrates is rapid during the latter stages of maturity coincident with the development of the ear, which constitutes so large a part of the whole plant and which is so completely digested by domestic animals. The result is that there is a decrease in the per cent of crude fiber as the maize plant ripens. The following analyses made at the Maine Station illustrate what in a general way has been verified by many stations:[1 2]

**Composition of Maize at Different Stages of Maturity.**

IN ONE HUNDRED PARTS WATER-FREE SUBSTANCE.

| Stage of growth | Ash | Protein | Crude fiber | Sugar | Starch | Total N-free ext. | Fat |
|---|---|---|---|---|---|---|---|
| Very immature, Aug. 15 . . . | 9.3 | 15.0 | 26.5 | 11.7 | .. | 46.6 | 2.6 |
| A few roasting-ears, Aug. 28 . . | 6.5 | 11.7 | 23.3 | 20.4 | 2.1 | 55.6 | 2.9 |
| All roasting stage, Sept. 4 . . | 6.2 | 11.4 | 19.7 | 20.6 | 4.9 | 59.7 | 3.0 |
| Some ears glazing, Sept. 12 . . | 5.6 | 9.6 | 19.3 | 21.1 | 5.3 | 62.5 | 3.0 |
| All ears glazed, Sept. 21 . . . | 5.9 | 9.2 | 18.6 | 16.5 | 15.4 | 63.3 | 3.0 |

352. **Influence of Maturity Upon Digestibility.**—A summary of American digestion experiments shows that both in the case

1 Me. Rpt. 1893, pt. 2, p. 25.

2 W. H. Jordan: The Feeding of Animals, p. 211.

of silage and maize fodder the digestibility is higher after glazing or denting than before:

**Digested from One Hundred Parts Organic Matter.**[1]

| | Maize fodder | | | Maize silage | | |
|---|---|---|---|---|---|---|
| | Max. | Min. | Av. | Max. | Min. | Av. |
| Cut before glazing, 13 experiments . . . . . | 71.4 | 53.6 | 65.7 | 77.8 | 56.6 | 67.4 |
| Cut after glazing, 10 experiments . . . . . | 74.2 | 61.2 | 70.7 | 80.2 | 65.2 | 73.6 |

Armsby[2] found that the total digestible food of the fully mature crop was from two to three times as great as the same variety in the silking stage and thirty-six per cent greater than at the time the ears were glazing.

353. **Influence of Maturity Upon Feeding Value.**—The Pennsylvania Station[3] and the Ohio State University[4] have determined the feeding value, when fed to milch cows, of equal areas of maize fodder when cut in the roasting-ear, silage stage, and when ripe or nearly so. In both cases the food value from equal areas measured in milk produced and increase or decrease of live weight was greatest in the intermediate stage. Compared with the earlier cutting, the intermediate stage gave much the best results, while compared with the late cutting, the difference was not so marked. The weight of field cured fodder increased with the stage of ripeness, the increase being greatest during the first interval. The percentage eaten, the fodder having been prepared with a feed cutter, was least in both instances in the early cut, greatest in one case in the medium cut and in the other instance in the late cut.

1 W. H. Jordan: The Feeding of Animals, p. 212.

2 Penn. Rpt. 1892, p. 23.

3 Penn. Rpt. 1892, p. 34.

4 D. A. Crowner, Thesis, 1896.

## II. USES AND PREPARATION FOR USE.

354. **Food for Domestic Animals** —The chief use of the maize crop is as a food for domestic animals. In connection with grass it is the meat producing material of the United States. The wonderful development of our pork industry is directly related to our maize crop. Sir John Lawes once said that the natural food of the civilized hog was barley meal. Had he lived in America, he would have said that the ears of maize are the natural food of the civilized hog. Maize silage forms an important element in the production of dairy products and its grain is largely used as a food for horses.

The food value of the grain of maize lies in its high net available energy due to its high percentage of easily digestible carbohydrates and fat and the absence of any deleterious substance. The plant other than the ear, whether green, ensiled or dry, is a palatable and healthful food for horses and ruminants, the dry matter being more digestible than that of timothy or clover hay. When properly prepared, the food value of the dry matter is rather less, and when the grain is added, rather more than that of timothy hay. The digestible nutrients in the grain and stover are about as two to one. The proportionate food value, however, is greater in the grain on account of its greater net available energy.

355. **Food for Human Consumption.**—While of less relative importance as a food for man, the actual amount of maize thus used is large. In the Southern States, where the proportion of maize to wheat grown is larger than in the Northern States, the grain of maize forms a large portion of the dietary of all classes. The meal, prepared by simply single grinding, either bolted or unbolted, is made into various forms of bread and cakes, without yeast or other leavening processes. Compared with products of wheat flour, the products of maize meal are less digestible, probably on account of the hull and the coarser

grinding. They are in every way, however, healthful and desirable articles of diet.

Hominy is prepared in the household by soaking the grains in the lye of wood ashes (KHO), which removes the hull, and also by hominy mills, which remove the hulls by a milling process. In the milling process of producing hominy the germ is more or less completely removed, thus adding to the keeping quality of the hominy, but somewhat lowering the per cent of protein. The maize grain is also used in some of the so-called breakfast foods other than hominy. These are low in protein and fat and high in carbohydrates, as compared with maize grain or meal, or with breakfast foods made from wheat or oats.

The ears of sweet maize are boiled when the grain is in the milk and eaten out of hand, forming a well-known and palatable article of diet. Experiments have been successfully conducted at the New Hampshire Station[1] in raising sweet maize under glass in order to furnish roasting ears out of season. "Canned corn," made by removing the grains of sweet maize when at this stage, placing in quart cans and subjecting to high heat, both before and after sealing, is the basis of an extensive industry. The mature sweet maize is also eaten parched.

356. **Manufactured Products.**—Glucose, starch, alcohol, whisky and malt liquors are also made from the grain of maize. Two forms of "corn starch" are made, one used in laundry work to stiffen cotton cloth and the other used for human consumption. The pith of the stems is used in the manufacture of explosives and for packing the sides of war vessels because of its property upon being pierced of quickly swelling and preventing ingress of water. The stems are used in the manufacture of paper and the husks for mats and mattresses.

357. **By-Products.**—The use of the maize plant in the manufacture of the above products has resulted in a large number

[1] N. H. Bul. 60 (1899).

of by-products. This is especially true in the manufacture of starch and glucose, where oil (262), gum, dextrine, rubber substitutes, germ oil meal, gluten meal, bran and gluten feed (mixture of gluten meal and maize bran) form important by-products. Distillers' grains are a by-product in the manufacture of alcohol, spirits and whisky and brewers' grains in the manufacture of beer. (466) Both distillers' and brewers' grains usually contain a mixture of several grains, commonly maize, barley and rye. Over twenty million bushels of grain, mostly maize, are used annually in the distilleries of the United States. The annual output of distillers' dried grains exceeds forty thousand tons and is largely exported to Germany for cattle feeding.

"There are quite generally three grades made, one from the distillation of alcohol and spirits, a second from the distillation of bourbon whiskey and a third from that of rye whiskey. The first named is the higher in feeding value, and is most apt to be of even quality, corn being the main, and, sometimes, the only grain used. The other grades vary in their composition in proportion to the relative proportion of corn, rye and malt used in the mashes; the more the corn and the less the smaller grains, the better the grade of the product."[1]

Gluten feed and distillers' and brewers' grains form acceptable foods for milch cows where large percentages of protein are required, and germ oil meal is especially desirable for calves and pigs where higher percentages of ash and fat unaccompanied with fiber are desirable. The by-products of glucose and starch factories are obtained by mechanical processes and the composition of each is rather uniform. The by-products of distilleries and breweries are the result of fermentative processes and may vary considerably in composition. Hominy feed is a by-product in the manufacture of hominy and differs from the original grain principally in containing a larger proportion of hull and embryo. The by-product in the manufacture of "cerealine" breakfast foods is known as cerealine feed.

[1] Vt. Rpt. 1903, p. 238.

When the pith is removed for the manufacture of explosives or packing for war vessels, the remainder, which may or may not include also the husks and blades, is ground into a coarse meal and is sold as "the new corn product." The Maryland Station[1] found it more digestible than timothy hay, for which it was successfully used as a substitute in feeding horses.

The following table gives analyses of by-products of maize used as food for domestic animals:

| | Water | Ash | Protein (N x 6.25) | Crude fiber | Nitrogen-free extract | Fat |
|---|---|---|---|---|---|---|
| Gluten meal | 9.2 | 1.1 | 36.9 | 2.2 | 46.7 | 3.9 |
| Maize bran | 9.1 | 1.3 | 9.9 | 12.1 | 62.0 | 5.6 |
| Gluten feed | 8.5 | 1.2 | 25.7 | 6.7 | 53.5 | 4.4 |
| Germ oil meal | 9.1 | 2.6 | 23.0 | 9.0 | 45.6 | 10.7 |
| Hominy feed | 9.3 | 2.7 | 11.2 | 4.5 | 63.7 | 8.6 |
| Cerealine feed | 10.2 | 2.6 | 11.2 | 4.6 | 63.3 | 8.1 |
| Distillers' grains[2] | 8.8 | 2.4 | 35.0 | 12.1 | 30.4 | 11.3 |
| New corn product | 8.5 | 5.4 | 6.5 | 27.3 | 49.3 | 2.9 |

1 Md. Bul. 51 (1897), p. 31.

2 XXXX alcohol grains (mostly maize). Vt. Rpt. 1903.

# XVII.

## MAIZE.

### I. PRODUCTION AND MARKETING.

358. **Maize Crop of the World.**—The production of maize in the world has varied during the years 1898 to 1902, inclusive, from 2,363 million bushels (1901) to 3,183 million bushels (1902) per annum, the average yearly production being 2,747 million bushels, which is slightly less than the production of wheat during the same period.

The following table gives the average annual production for half decade by continents in million bushels:

| | 1898 to 1902, inclusive |
|---|---|
| Europe | 471 |
| North America | 2,149 |
| South America | 86 |
| Australasia | 9 |
| Africa | 32 |
| Total | 2,747 |

Aside from the United States, the most important maize producing countries are Hungary, Roumania, Italy, Russia, Mexico, Argentina and Egypt. Great Britain, Ireland, Germany and the countries farther north do not raise maize, except occasionally as a vegetable, on account of lack of heat and sunshine during the growing season. During the past five years the production of maize has developed more rapidly in Argentina than elsewhere. Argentina appears to have the largest body of undeveloped land adapted to raising maize of any country.

**359. Maize in the United States.**—One-fifth of the area in improved land, one-third the area in crops of all kinds, except pasture, and one-half the area in cereal crops is devoted to raising maize. In 1899, while thirty-five per cent of the farms in the United States raised wheat, eighty-two per cent raised maize.

The average annual production of maize in the United States for three decades, according to the estimates of the United States Department of Agriculture, is given below:

| | 1870–79 | 1880–89 | 1890–99 |
|---|---|---|---|
| Area, acres | 44,000,000 | 71,000,000 | 76,000,000 |
| Yield, bushels | 1,184,000,000 | 1,703,000,000 | 1,835,000,000 |
| Value, dollars | 505,000,000 | 669,000,000 | 610,000,000 |
| Value per bushel, dollars | 0.43 | 0.39 | 0.35 |
| Yield per acre, bushels | 27.1 | 24.1 | 24.1 |
| Value per acre, dollars | 11.54 | 9.48 | 8.44 |

The estimates of the United States Department of Agriculture make it appear that the average annual production during the ninety decade was only slightly larger than the eighty decade, while the census returns indicate that in 1899 the acreage was thirty-two per cent and the production twenty-six per cent greater than in 1889. The average gross value of an acre of maize has been less during all the decades than that of wheat, though in the decline in value of both crops per acre, that of wheat has been more rapid than maize, which would seem to indicate that maize is relatively increasing in value. While in fifty years the production of wheat has increased six and one-half times, that of maize has increased four and one-half times.

**360. Maize Surplus States.**—Over one-half of the entire maize crop of the United States is contributed from five States, and over two-thirds from seven States, in the following order: Illinois, Iowa, Kansas, Nebraska, Missouri, Indiana, Ohio.

These seven States are known as the maize surplus States, because they are practically the only States which supply the commercial centers with maize. Notwithstanding the fact that over ninety per cent of the entire crop was limited to twenty-one States, outside of these seven surplus States, maize is largely consumed where raised. Other States besides the seven named, therefore, need not be taken into consideration in the commerce of this crop, except as they need more or less from the surplus States for consumption. Although the tendency of maize production is to concentrate in areas affording the greatest natural advantages, and although the seven just named will continue for years to be the surplus States, statistics show that other States that do not make a business of maize raising, notably those on the Atlantic seaboard, are in recent years making greater relative gains in maize production.

361. **Center of Maize Production.**—During the last half century the center of maize production has moved from southeastern Ohio to southwestern Illinois (90° 27′ 6″ W. Long., and 39° 19′ 33″ N. Lat.), nearly due west 480 miles. The westward movement of wheat has been one-half faster. While maize has moved northward only about five miles, wheat has moved northward ninety-nine miles. For twenty years the center of maize production has been nearly stationary.

Map showing the distribution of maize produced in the United States in 1900.

362. **Production per Population.**—The production of maize has increased more rapidly than population during the past fifty years. It is estimated, however, that the number of bushels of maize per capita retained for consumption in the United States was more in the decade 1880-89 than in the succeeding decade,

being 28.6 bushels per capita in the former and 25.5 bushels in the latter. This is the heaviest rate of consumption of any cereal by any people in the world. It is nearly twice as much according to population as the consumption of all the cereals in Europe.

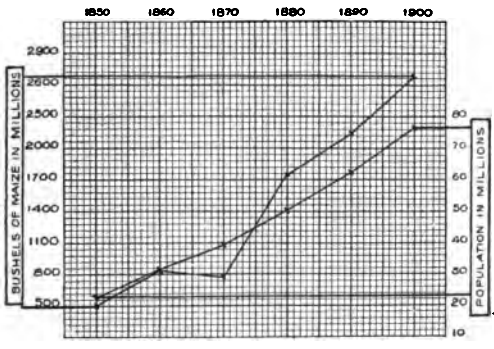



Diagram showing the increase in the production of maize as compared with the population in the United States during fifty years, according to the reports of the census of 1900.

363. **Yield per Acre.**—The average yield of maize grain during the last two decades was twenty-four and one-tenth bushels,—nearly twice that of wheat. There are several Southern States in which the annual yield is less than ten bushels per acre. In the seven surplus maize States the annual yield of maize is thirty-five bushels per acre. In these States nothing less than fifty bushels per acre is considered satisfactory by progressive farmers, and yields of seventy-five to ninety bushels per acre are not at all uncommon; while yields of more than 100 bushels per acre are frequently reported.

364. **Export of Maize.**—While a much smaller percentage of the maize raised is exported than of wheat, the amount is large and is increasing. But for the great shortage of the maize crop of 1901, the average annual exportation of maize for the five years 1898-1902 would have shown an enormous increase over that of the five years 1893-1897. Notwithstanding this great decrease, which makes the exportation of maize in 1902 by far the smallest for the ten years 1893-1902, the total exportation for the five years given shows substantial gains over any

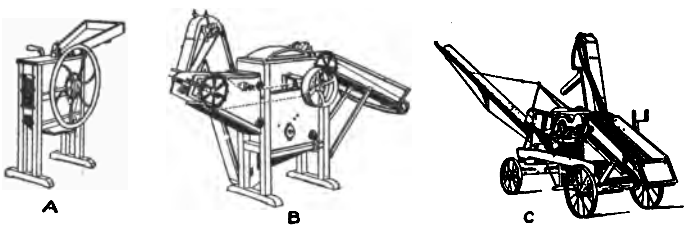
other five years preceding. The total exportation for the five years 1898-1902 was approximately 160 million bushels of grain, while that of the five years immediately preceding was but little more than half that amount,—something less than eighty-three million bushels.

Ninety-two per cent of this great export trade is handled by nine ports, named in the order of their importance, as follows: Baltimore, New York, Philadelphia, New Orleans, Boston, Newport News, Chicago, Norfolk and Portsmouth, and Detroit.

The export trade in maize meal is also fast assuming large proportions. The average annual exportation of this product for the five years 1898-1902 was nearly 800 thousand barrels (3,200,000 bushels), more than twice that for the years 1893-1897. New York, Newport News and Baltimore, in the order named, handled the bulk of this trade.[1]

The important importing countries have been Great Britain and Ireland, Germany, Netherlands, Canada, Denmark, Belgium and France. Cuba has imported more than a million bushels of grain annually during the five years 1898-1902. Other countries which export important quantities of maize are Argentina, Roumania and Russia.

365. **Marketing.**—The legal weight per bushel of maize in most States is fifty-six pounds per bushel, although the usual



Types of shellers for farm use: A, one-hole hand sheller; B, two-hole power sheller; C, itinerant power sheller, made with four to eight holes for feeding in the ears.

[1] U. S. Statistical Abstract, 1902, pp. 301-303.

custom well understood in many localities between seller and buyer is sixty pounds per bushel. A large portion of the maize delivered to the country elevator is in the ear, where it is usually shelled before shipping. In most States the legal weight per bushel of maize on the ear is seventy pounds, although it is sixty-eight pounds in a number of States. In some localities, custom requires that a larger number of pounds be given for new maize until a given date, say eighty pounds per bushel until December first.

366. **Commercial Grades.**—The system of inspection for maize is the same as that for wheat and other grains. As in wheat, soundness, plumpness and mixture of foreign substances or of maize of different color fix the grade. The weight of measured bushels does not enter into the determination of the grade. The Illinois Board of Railroad and Warehouse Commissioners recognizes the following classes and grades:

Yellow maize, Nos. 1, 2 and 3.
White maize, Nos. 1, 2 and 3.
Maize, Nos. 1, 2, 3 and 4.

Usually in the Chicago market, more maize is dealt in than yellow and white combined, and much more yellow maize than white maize. The grade of all classes of maize usually dealt in is No. 3, No. 4 maize being much more common than No. 2. The following are the rules for grading yellow maize:

No. 1 yellow maize shall be yellow, sound, dry, plump and well cleaned.

No. 2 yellow maize shall be three-fourths yellow, dry, reasonably clean, but not plump enough for No. 1.

No. 3 yellow maize shall be three-fourths yellow, reasonably dry and reasonably clean, but not sufficiently sound for No. 2.

Rules for white maize are identical with those for yellow, except three-fourths reads seven-eighths. Under these rules, all maize that is less than three-fourths yellow and at the same time less than seven-eighths white is maize.

367. **Grade Uniformity.**—Scofield[1] has pointed out that the essential elements in grading maize are: (1) the moisture, (2) the percentage of colors in mixtures, (3) the percentage of damaged grains, and (4) the percentage of broken grains and dirt. He proposes to put all dent maize into three classes as follows:

1. Yellow maize; at least 95 per cent yellow.
2. White maize; at least 98 per cent white.
3. Mixed maize; all maize not included above.

The maximum limits for each grade of yellow maize are suggested in the following table:

| Trade no. | Per cent of water | | Per cent damaged | Per cent of dirt and broken grains |
|---|---|---|---|---|
| | Nov.–Mar. | Apr.–Oct. | | |
| 1 . . . | 13 | 12 | 0 | 0 |
| 2 . . . | 15 | 14 | 1 | 2 |
| 3 . . . | 17 | 16 | 3 | 3 |
| 4 . . . | 19 | 18 | 6 | 5 |

## II. HISTORY.

368. **Nativity.**—The records of the early voyagers prove that maize was cultivated on the American continent from Maine to Chile at the time of its discovery. It was then the great bread plant of the New World. Numerous varieties of maize have been found in the ancient tombs of Mexico, Peru and New Mexico. These monuments are supposed to be two thousand years old. As there were many varieties at this time, the cultivation of maize must have been considerably more ancient, although not necessarily so ancient as that of wheat. There was a semi-civilized race of people in Peru, Mexico, and even in New Mexico, who made considerable use of maize, using it boiled and roasted when green, and grinding it and making it into bread when ripe.

1 U. S. Dept. Agr., Bu. Pl. Ind. Bul. 41.

369. **Value to Colonists.**—Maize was the salvation of many of the early colonies, preventing the colonists and their stock from starving. The tame grasses had not been introduced, so that besides maize stover their stock had nothing but salt marsh hay.

The early settlers learned the cultivation of maize from the Indians. The James River settlers, under the tuition of the Indians, began to raise maize in 1608, and within three years they appeared to have as many as thirty acres under cultivation. The Pilgrims found it in cultivation by the Indians on their arrival at Plymouth, and began its cultivation in 1621, manuring, as the Indians did, with fish.

"According to the manner of the Indians we manured our ground with herrings, or rather shads, which we have in great abundance and take with ease at our doors.

"You may see in one township a hundred acres together set with these fish, every acre taking a thousand of them, and an acre thus dressed will produce and yield as much corn as three acres without fish."

In the Jamestown settlement they planted pumpkins and melons in the hill with the maize.

370. **Introduction into Eastern Continent.** — Maize is pretty certainly of American origin. It has been introduced into Europe, Asia and Africa since the discovery of America. After its introduction into the old continent it spread very rapidly across northern Africa and southern Europe and across Asia into China. The rapidity with which it spread gave rise to disputes as to its origin and considerable confusion as to its name.

Maize has been known by the following curious names in Europe: Turkish corn, Italian corn, Roman wheat, Sicilian wheat, Indian wheat, Spanish wheat, Barbary wheat, Guinea and Egyptian wheat. These names were given it in various places on account of the country in which it was supposed to have originated. They simply indicate the country from which and through which maize was introduced. The names, with the exception of Indian, are those of places bordering on the Mediterranean Sea. This would seem to indicate that maize

was brought from America in vessels which sailed into the Mediterranean Sea and landed in the various countries denoted. The climate on both sides of the Mediterranean is fairly well adapted to the growth of maize. The rapid introduction into these countries of so striking a plant and its spread therefrom is not a matter of surprise.

## Practicums.

371. DESCRIPTION OF MAIZE PLANT.

Name of variety . . . . Date . . . .

1. Maturity of plant silking: roasting ear; partly dented or glazed; dented or glazed; nearly ripe; ripe.
2. Height of plant: average of ten plants . . . feet . . . inches
3. Proportion of ears: number of ears on one hundred stalks . .
4. Barren stalks: number in one hundred stalks . . .
5. Position of ear: pointing upward; horizontal; pointing downward.
6. Husks: adherent; medium; non-adherent.
7. Husks: abundant; medium; scanty.
8. Length of shank: distance from node to base of ear,—average of ten plants . . .
9. Circumference of stem: at middle of internode between second and third node from ground . . .
10. Circumference of stem: at middle of internode below main ear . . .
11. Number of leaves: average of ten plants . . .
12. Average width of leaf blades: average of five plants . .
13. Average length of leaf blades: average of five plants . . .
14. Length of tassel: average of ten plants . . .

372. THE CHARACTERS OF THE GRAIN.—Give each student twenty-five to thirty grains each of five types of maize or five varieties of a single type. For Nos. 12 to 18, a number of grains should be soaked in hot water for thirty minutes, or in cold water for twenty-four hours. For taking measurements, furnish each student with a sheet of cross-section paper.

Name of variety . . . . Date . . . .

1. Weight: ten average grains in duplicate (a) . . . (b) . . .
2. Length: ten average grains in duplicate (a) . . . (b) . . .
3. Width: ten average grains in duplicate (a) . . . (b) . . .
4. Thickness: ten average grains in duplicate (a) . . . (b) . . .
5. Ratio of width to length: divide length of ten grains by width of ten grains (a) . . . (b) . . .
6. Ratio of thickness to width: divide width of ten grains by thickness of ten grains (a) . . . (b) . . .
7. Shape; flat; spheroidal; conical.

8. Shape (side view): cuneate wedge-shape; rounded-cuneate; truncate-cuneate; shoe-peg form; rectangular; rounded corners.
9. Summit: rostrate; mucronate; rounded; flat; dented.
10. When dented: dimple; long dimple; creased; pinched; ligulate.
11. Color: white; yellow; golden; red; purple.
12. Place of color: endosperm; aleurone layer; hull.
13. Character of endosperm: corneous; partly corneous; farinaceous; glucose.
14. Proportion of corneous endosperm, if dent variety: large; medium; small.
15. Size of embryo: large; medium; small.
16. Sketch of cross-section: show arrangement to scale of embryo, glossy and white endosperm.
17. Sketch of transverse section: show arrangement to scale of embryo, glossy and white endosperm.
18. Sketch of lateral section: show arrangement to scale of embryo, glossy and white endosperm.

373. THE CHARACTERS OF THE EAR.—Give each student two or more ears of each of the five types of maize, or five different varieties of the same type. Ten ears of a given type or variety are none too many for a thorough study, but with larger classes it may be necessary to economize in material. Ears properly labeled, showing characters mentioned below, should be displayed for guidance of students. (220)

Name of variety . . . . Date . . . .

1. Color of grain: white; yellow; golden; red; purple.
2. Color of cob: white; light red; deep red.
3. Surface: smooth; medium; rough; very rough.
4. Sulci: absent; apparent; narrow; distinct; very distinct.
5. Pairs of rows: distichous; not distichous.
6. Number of rows: one-fourth length from butt . . . ; from tip . . .
7. Direction of rows: rectilinear; spiral to right; spiral to left; irregular.
8. Grains: very loose; loose; firm; mosaic-like.
9. Grains: upright; sloping; imbricated.
10. Ear: cylindrical; cylindraceous; slowly tapering; tapering; distinctly tapering; flat.
11. Butt: even; shallow rounded; moderately rounded; deeply rounded.
12. Butt: depressed; compressed; depressed-rounded; depressed-compressed; enlarged; expanded; open.
13. Tip: sides of cob exposed; end exposed; end covered; terminal grain.
14. Juncture of ear stalk: large; medium; small.
15. Length of ear (extreme length): (a) . . . (b) . . .
16. Circumference of ear one-third distance from butt: (a) . . . (b) . . .
17. Weight of ear: (a) . . . (b) . . .
18. Weight of cob: (a) . . . (b) . . .
19. Percentage of grain: (a) . . . (b) . . .
20. Circumference of cob one-third distance from butt: (a) . . . (b) . . .
21. Ratio of circumference of cob to circumference of ear: (a) . . . (b) . . .

374. SCORE CARD FOR DENT MAIZE.[1]

Furnish each student with a sample consisting of ten ears of maize.

1. TRUENESS TO TYPE OR BREED CHARACTERISTICS, 10 POINTS.—The ten ears in the sample should possess similar or like characteristics, and should be true to the variety which they represent.

2. SHAPE OF EAR, 10 POINTS.—The shape of the ear should conform to the variety type. Ear should be full and strong in central portion and not taper too rapidly toward the tip.

3. PURITY (a) IN GRAIN, 5 POINTS.—Color of grain should be true to variety and free from mixture. For one or two mixed grains, a cut of one-fourth point; for four or more mixed grains, a cut of one-half point should be made. Difference in shade of color must be scored according to variety characteristics.

(b) IN COB, 5 POINTS.—An ear with white cob in yellow maize or red cob in white maize, should be disqualified or marked zero. This mixture reduces the value of the maize for seed purposes, indicates lack of purity, and tends towards a too wide variation in time of maturity, size and shape of grains.

4. VITALITY OR SEED CONDITION, 10 POINTS.—Maize should be in good seed condition, being capable of producing strong, vigorous growth and yield.

5. TIPS, 5 POINTS.—The form of tip should be regular; grains near tip should be of regular shape and size. The proportion of tip covered or filled must be considered. Long pointed tips as well as short flattened or double tips are objectionable.

6. BUTTS, 5 POINTS.—The rows of grains should extend in regular order over the butt, leaving a deep depression when the shank is removed. Open and swelled butts, depressed and flat butts, with flattened glazed grains, are objectionable and must be cut according to the judgment of the scorer.

7. GRAINS (a) UNIFORMITY OF, 10 POINTS; (b) SHAPE OF, 5 POINTS.—The grains should be uniform in shape and size, making it possible to secure uniformity in dropping with the planter, and consequently a good stand. The grains should also be not only uniform on individual ear, but uniform in color and true to variety type. The grains should be so shaped that their edges touch from tip to crown.

8. LENGTH OF EAR, 10 POINTS.—The length of ear varies according to variety, type, and the characteristics sought for by individual breeders. Uniformity in length is to be sought for in a sample, and a sample having an even length of ears should score higher than one that varies, even if it be within the limits. Instructor will set limits for length of ears of sample according to variety, allowing a variation of one inch. The sum of the excesses and deficiencies in inches shall constitute a cut in points.

9. CIRCUMFERENCE OF EAR, 5 POINTS.—The circumference of the ear will vary according to the variety and the latitude. The circumference of the ear should be in symmetry with its length. An ear too great in circumference for its length is generally slow in maturing, and too frequently results in soft maize. Instructor will set limits for circumference of ears of sample according to variety, allowing a variation of one-half inch. The sum of the excesses and deficiencies in inches shall

[1] The score card of the Iowa State College slightly modified. Iowa Bul. 77 (1904).

constitute a cut in points. Measure the circumference at one-third the distance from the butt to the tip of the ear.

10. (a) FURROWS BETWEEN ROWS, 5 POINTS.—The furrows between the rows of grains should be of sufficient size to permit the maize to dry out readily, but not so large as to lose in proportion of grain to cob.

(b) SPACE BETWEEN TIPS OF GRAINS AT COB, 5 POINTS.—This is objectionable, as it indicates immaturity, weak constitution and poor feeding value.

11. PROPORTION OF GRAIN TO COB, 10 POINTS.—The proportion of grain is determined by weight. Depth of grains, size of cob, maturity furrows and space at cob, all affect the proportion. In determining the proportion of grain to cob, weigh and shell every alternate ear in the exhibit. Weigh the grain and subtract from weight of ears, giving weight of grain; divide the weight of grain by the total weight of ears, which will give the per cent of grain. Per cent of grain should be from 86 to 87. For each per cent short of standard, a cut of one and one-half points should be made.

375. DETERMINATION OF COMMERCIAL GRADES OF MAIZE.—Give each student two to four pounds of maize of two or more unlike samples and have him determine the proper grade. (367)

(a) Per cent of water: grind a sufficient amount of maize into a coarse meal and determine per cent of water in thirty grams by drying to constant weight at 102° C.
(b) Color: determine percentage of color in 500 grains by count.
(c) Damaged grains: determine percentage of rotten, moldy or otherwise unsound grains in 500 grains by count.
(d) Broken grains and dirt: determine on the basis of weights the percentage of all broken grains, meal, dirt, chaff and other foreign material in two or more pounds.

376. COLLATERAL READING.

Natural Distribution of Roots in Field Soils. By F. H. King. Ninth Ann. Rpt. of the Wis. Agr. Expt. Sta. (1892), pp. 112-120.

Varieties of Corn. By E. L. Sturtevant. U. S. Dept. of Agr., Office of Expt. Sta. Bul. 57.

Manual of Corn Judging. By A. D. Shamel. New York: Orange Judd Company (1903).

Xenia, or the Immediate Effect of Pollen in Maize. By H. J. Webber. U. S. Dept. of Agr., Div. Veg. Phys. and Path. Bul. 22 (1900).

Methods of Corn Breeding. By C. G. Hopkins. Ill. Agr. Expt. Sta. Bul. 82 (1902).

Selecting and Preparing Seed Corn. By P. G. Holden. Iowa Agr. Expt. Sta. Bul. 77 (1904).

The Maintenance of Fertility. By Charles E. Thorne. Ohio Agr. Expt. Sta. Bul. 110 (1899).

Ten Years of Experiments in Corn Culture. By R. J. Redding. Ga. Agr. Expt. Sta. Bul. 46 (1899), pp. 73-75.

Modern Silage Methods. The Silver Manufacturing Co., Salem, Ohio.

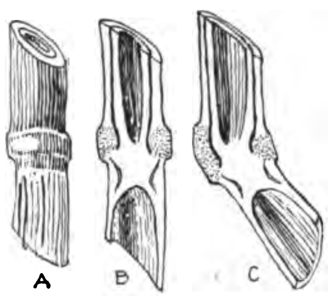
Maize. Origin of Cultivated Plants. By Alphonse De Candolle. New York: D. Appleton & Co. (1902), pp. 387-397.

# XVIII.

## OATS.

### I. STRUCTURE.

377. **Relationships.**—The tribe (*Avenae*) to which the oat (*Avena sativa* L.) belongs differs from the tribe (*Hordeae*) to which wheat, rye and barley belong, in having the inflorescence in panicles instead of in spikes, and in having a crooked awn on the back of the flowering glume, instead of a straight awn at the end. To this tribe belong few economic plants. *Arrhenatherum avenaceum* Beauv. is somewhat extensively cultivated in France under the name of Ray Grass. It is only sparingly cultivated in America under the name of Tall Oat Grass. Velvet Grass (*Holcus lanatus* L.) is also occasionally sown as a pasture grass.



Nodes of oats: A, exterior view; B, cross-section of straight culm; C, cross-section showing that a culm after it has fallen becomes erect by the growth on its lower side of the sheath node, not the culm node.

378. **The Plant.**—The habit of growth of the roots is similar to that of wheat. The culms are somewhat larger in diameter and of rather softer tissue. Environment has a greater influence upon length of culm of oats than of winter wheat and rye. Height of culm varies from two to five feet; probably the average height is three and a half feet. The leaves are more abundant, the blade broader, and the ligule more pronounced than in wheat.

The Ohio Station found during seven years an average of one

pound of grain to two and one-tenth pounds of straw when fertilizers were used, and one of grain to two of straw when no fertilizers were used.[1] The Illinois Station has found as high as two and seven-tenths pounds of straw per each pound of grain,[2] and as low as one and two-tenths pounds in different seasons under otherwise like conditions.[3] Kansas Station found a variation of from four and one-tenth to one and two-tenths pounds of straw to one pound of grain due to season.[4] In general, the more favorable the season the more fertile the soil, and the later the variety or the later the seeding the greater is the proportion of straw to grain.

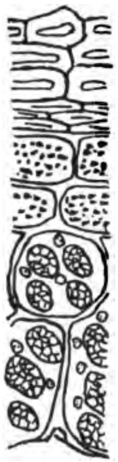
379. **Inflorescence.**—A typical panicle is nine to twelve inches long, contains from three to five whorls of branches and bears about seventy-five spikelets. The branches arise from alternate sides of the rachis and vary in length and position; thus the panicle may be open or closed; symmetrical or one-sided. Each spikelet is at the end of a flexible pedicel of variable length. The spikelet contains two or more flowers; only two usually mature, the lower one always developing into the larger grain. The outer glumes are membraneous and considerably larger (three-fourths to one inch) than the flowering glume. The color of the latter varies from yellow to reddish brown and black. The flowering glume of the lower flower usually partially encloses that of the upper flower. The awn, when it occurs, is on the back (not at the tip) of the flowering glume, and usually occurs only in the lower flower of the spikelet. The palea is smaller than the flowering glume and enclosed

A spikelet of oats: 1, outer glumes; 2, lower flower; 3, upper flower; 4, rudiment of third flower

1 Ohio Rpt. 1896, p. 142.
2 Ill. Bul. 12 (1890), p. 355.
3 Ill. Bul. 31 (1894), p. 384.
4 Kan. Bul. 42 (1893), p. 83.

within the latter. The organs of reproduction are quite similar to those in wheat. (56)

380. **The Grain.**—The oat kernel, except in hull-less varieties, remains enclosed in the flowering glume and palea. These parts are usually referred to as the oat hull, but are entirely different from the hull of maize (228) or the bran of wheat. (64) In this book the caryopsis of the oat will be called the kernel, and the kernel plus the hull will be called the grain. In general form and structure the oat kernel is similar to the grain of wheat, but is rather more elongated, while the pericarp is characterized by its hairy surface. Richardson found in an average of 166 varieties that 100 grains weighed 2.5 grams, with variations from 1.75 to 3.75 grams per hundred grains.[1]




Magnified section of portion of oat kernel: *p*, pericarp; *t*, testa; *a*, double row of aleurone cells; *s*, endosperm with compound starch grains. Nucellus not shown in this section. (After Pammel.)

381. **Relation of Hull to Kernel.**—The quality of oats depends principally upon the proportion of hull to kernel. The per cent of hull depends both upon the variety and upon the conditions of growth, varying from at least twenty to forty-five per cent. American varieties contain on an average about thirty per cent of hull and seventy per cent of kernel. It has been demonstrated that there is no necessary relation between weight per bushel or shape of grain and the per cent of kernel or food value. The Illinois Station, working during five years with from thirty to sixty varieties, the seed of which was from various sources, but the crops all grown under like conditions, found that generally varieties with long, slender, comparatively light grains had the largest per cent of kernel.[2] The Ohio Station, working with seventy varieties

1 U. S. Dept. of Agr., Div. of Chem. Bul. 9.

2 Ill. Buls. 7, 12, 19 and 23.

one season, found that the Welcome or short, plump grain group (385) contained a higher percentage of kernel than the Seizure group, which has longer and more slender grains. While in the Welcome group the varieties with the highest weight per bushel contained the highest per cent of kernel, the reverse was the case with the Seizure group.[1] Saunders believes that the results at Ottawa prove that with a given variety the actual weight of hull per grain is the same without reference to the weight per bushel.[2]

Since the hull (flowering glume and palea) develops long before the kernel, it would seem that with a given variety any unfavorable environment which prevents the grain from filling fully would both decrease the per cent of kernel and the weight per bushel. If, however, a large number of varieties are grown under the same conditions, it is probable that those varieties best suited to the environment would develop their kernels most completely and thus have the highest per cent of kernel. Thus the per cent of kernel might in some instances be the highest in varieties with short, plump grains, and in other instances in those with long, slender ones, depending upon their adaptability to the given region or season.

382. **Weight per Bushel.**—The legal weight per bushel in all States of the United States is thirty-two pounds, except in Idaho (thirty-six), Maine, New Jersey, Virginia (each thirty) and Maryland (twenty-six). In Canada it is thirty-four pounds. Oats may vary in weight from twenty-five to fifty pounds per bushel, the lighter weight being found in the more southern climates. Richardson found the average weight per bushel of 166 varieties gathered from various sections of the United States to be thirty-seven pounds. In order to increase the weight per bushel and consequently the commercial quality, elevators frequently resort to a process known as clipping.

1 Ohio Bul. 57, p. 108.

2 Can. Farms Rpt. 1903, p. 8.

## II. COMPOSITION.

383. **Composition.**—The average of American analyses is as follows:

| | Oat grain | Oat kernel | Oat straw | Oat hay (cut in milk) | Oat hull |
|---|---|---|---|---|---|
| Water . . . | 11.0 | 7.9 | 9.2 | 15.0 | 7.3 |
| Ash . . . | 3.0 | 2.0 | 5.1 | 5.2 | 6.7 |
| Protein (N x 6.25) | 11.8 | 14.7 | 4.0 | 9.3 | 3.3 |
| Crude fiber . . | 9.5 | 0.9 | 37.0 | 29.2 | 29.7 |
| Nitrogen-free extract | 59.7 | 67.4 | 42.4 | 39.0 | 52.0 |
| Fat . . . | 5.0 | 7.1 | 2.3 | 2.3 | 1.0 |

Rather wide variations are found in the composition of the oat grain, due doubtless to the variation in percentage of hull, since the composition of the oat kernel shows only moderate variations. Taking the grain as a whole, oats differ from maize principally in having a larger per cent of crude fiber at the expense of starch. The kernel is richer in protein and fat than the corresponding part of any of our other cereals. Oat straw has a higher percentage of protein and a lower percentage of crude fiber than wheat or rye straw. The composition of oat hay cut when the grain was in the milk is very similar to that of timothy hay.

No coherent substance similar to gluten in wheat is to be obtained from the oat kernel; hence light bread cannot be made from it. Osborne has found that the proteids of the oat kernel undergo great changes when brought in contact with water or sodium chloride solution. It is necessary, therefore, to distinguish between the primary and secondary proteids of the oat kernel. Of primary proteids, the oat kernel contains about one and one-fourth per cent of an alcohol-soluble proteid; about one and one-half per cent of salt-soluble proteid or globulin, while the rest of the proteids contained in the oat kernel is an alkali-soluble body. This substance which forms the larger portion of the proteids has been given the name *avenine*.[1]

[1] Memoirs National Academy of Sciences, Vol. VI, p. 51; also Conn. Rpt. 1891, p. 134.

384. **Germination.**—Saunders has reported the average germination of four samples of oats during six years as follows: 90, 93, 78, 67, 54 and 30 per cent. The viability was greater than with wheat, barley, peas or flax.[1] Kinzel found that the percentage of germinable seed steadily increased for eight to ten months, after which there was a decrease.[2] The Ohio Station found an average yield during five years of forty-eight bushels per acre where seed of the previous year's growth was used, and forty-five bushels per acre where seed was one year older.[3]

The Wisconsin Station reports that soaking oats in a solution of two and one-half parts of formaldehyde to 1,000 parts of water decreased germination from six to seventeen per cent.[4] An increased yield has been observed in some instances from hot water and potassium sulphide treatment beyond that resulting from replacing smutted panicles with sound ones. This may be explained by supposing that many plants are attacked with smut without developing spores when seed is not treated, and by its possible higher germinative energy. Kellerman found that treatment with hot water and potassium sulphide generally caused better and greater germination;[5] while the Wyoming Station found copper sulphate, hot water and potassium sulphide generally injurious.

## III. VARIETIES.

385. **Classification.**—There are spring and winter (fall) varieties of oats. The winter varieties are principally grown south of the southern boundary of Virginia, Kentucky, Missouri and Kansas, or about 37° N. Lat., where they are the chief

1 Can. Expt. Farms Rpt. 1903, p. 44.

2 Landw. Vers. Stat. 54 (1900), No. 1-2, p. 123.

3 Ohio Bul. 138 (1903), p. 48.

4 Wis. Rpt. 1902, p. 268.

5 Ohio Bul. 3 Tech. ser. (1893), p. 201.

varieties grown. The area of cultivation of winter oats is gradually extending northward. Where successfully grown they are to be preferred to spring varieties, because of their more vigorous early growth in the spring and their earlier ripening. At the Alabama Station fall sowing gave about twice the yield of grain and straw as spring sowing.[1] There is, however, greater danger of absolute failure of fall seeding on account of winter killing.

Oats may be further classified according to their date of ripening, according to color and shape of grain and according to the shape of the panicle. The panicle may be spreading or open, or the branches may hang mostly upon one side of the rachis and be more upright, which gives the panicle a closed appearance. Such varieties are known as side oats. There are all degrees of variation between the varieties with open and closed panicles.

Variety with open or spreading panicle.

There are varieties of oats known as hull-less oats, in which the flowering glume and palea are removed upon threshing. These varieties may have either open or closed panicles. On account of the smaller yield, due in part, at least, to the removal of the hull, they are not generally raised.

1 Ala. Bul. 95, p. 165.

The Ohio Station, which has tested seventy-one varieties for ten years, has divided these varieties into four groups: (1) Welcome group, with open panicle, coarse straw and short, plump grain, includes twenty-one varieties; (2) Wide Awake group, grain longer and more pointed, requiring slightly longer season, includes twenty-three varieties; (3) Seizure group, panicle one-sided, stiff straw, still longer season, includes thirteen varieties; (4) Mixed group, in which varieties are placed not clearly belonging in any of the above groups.

Variety with closed or one-sided panicle.

386. **Value of Different Types and Varieties.**— Carleton states that side oats are usually white or black; that white and black varieties of any type are usually found in northern regions; that red varieties usually, and gray varieties almost entirely, are grown as winter oats.[1] Experiments seem to indicate that there is no material difference in yield between varieties with open and closed panicles, between varieties of different colored grains, or between varieties having short, plump grains, and those having long, slender grains, and consequently between varieties of different weight per bushel. In America there are more early maturing varieties with short, plump, white grains and open panicles than any other kind; and at the Ohio Station and at the Ontario Agricultural College ranked rather better than other types.[2]

While it cannot, perhaps, be demonstrated that early maturing varieties are more prolific than late maturing varieties, they have the advantage in that their growth and maturity are during the

[1] Rpt. Kan. St. Bd. Agr., Quar. ending March 1, 1904, p. 19.

[2] Ohio Bul. 138 (1903), p. 45, and Ont. Agr. Col. and Expt. Farms Rpt. 1897, p. 154.

cooler portion of the season, and also because they may often be harvested so as to avoid storms which injure the late varieties. In some localities early maturing varieties are desirable in order that they may be harvested in time to prepare for the succeeding crop. There is a difference of about two weeks in varieties grown in this country when grown side by side in a given locality. At the Ohio Station the average length of seasons during ten years varied for seventy-one varieties from ninety-eight to 105 days, except in Early Ripe, which was eighty-seven days. During eight years North Dakota Station has found an average variety variation of from eighty-eight to 102 days, while the extreme limits due to both season and variety were eighty to 118 days.[1] Early varieties usually have shorter stems, and are, therefore, less likely to lodge.

387. **Varieties of Oats.**—Twenty-eight stations have tested varieties of oats from one to fifteen years and have obtained satisfactory results with 125 different varieties. Of these varieties, only sixteen are recommended by four or more stations. Two are winter varieties suited to sowing in the South in the fall, viz., Red Rust Proof, 8;[2] Virginia Gray, 4. Of the fourteen spring varieties, eleven are white with open panicles, as follows: American Banner, 10; Badger Queen, 6; Lincoln, 5; Wide Awake, 5; Improved American, 4; Clydesdale, 4; White Bonanza, 4; Pringle's Progress, 4; Siberian, 4; Welcome, 4; White Wonder, 4. Two varieties have closed panicles, White Russian, 4, and Black Russian, 4, with the color of grain as indicated in name. Burt (synonym May) is recommended by four stations: Alabama, Arkansas, Georgia and Mississippi, where an early maturing spring variety is desired.

There is a group of varieties of which Virginia is the type that are especially adapted to growing for grazing or for hay. They are hardy, have tall fine straw, a low percentage of grain

[1] No. Dak. Bul. 52, p. 109.

[2] Number of stations recommending the variety.

and a long season of growth. The Red Rust Proof appears to have a wide adaptation to the conditions existing in the Southern States.

"It can be sown both in fall and in late winter in this latitude. It is generally not greatly injured by rust, but is rust resistant rather than rust proof. The straw is short, an objection in very poor or stony land, since short straw means loss in harvesting. The height of straw can be increased by the liberal use of nitrogenous fertilizers, such as cotton seed, cotton seed meal and nitrate of soda."[1]

The station results clearly indicate that there are types of oats specially adapted to Southern conditions, but do not appear to indicate any marked adaptability among the North Atlantic, North Central and Western States.

388. **Improvement of Varieties.**—The qualities to be sought in oats are (1) high percentage of kernel, (2) yield, and (3), to meet commercial demands, high weight per bushel, which is not necessarily related to per cent of kernel. Factors which influence yield, and to some extent quality, are (1) hardiness, (2) earliness, (3) stiffness of straw, (4) resistance to heat and drouth, (5) rust resistance. Oats have been improved by selection and by crossing. Improvement may be accomplished through continuous seed selection (402) and through the selection of individual plants by means of the breeding nursery. (108) The oat grower may keep his variety true to type and possibly improve it by maintaining a small seed patch (say an acre) on which is grown seed selected from the best portion of his field or the best plants of his seed patch the previous year.

389. **Introduction of New Varieties.** — The most important variety improvement in America has been due to the introduction of new varieties from northern Europe. Probably more new varieties of oats are imported and distributed by seedsmen than of any other cereal. It is not clear, however, to what extent the improvement has been merely in weight per bushel rather than in yield, except in instances where specially tested

[1] Ala. Bul. 95 (1898), p. 161.

varieties have been introduced as described below, and it seems probable that rigid selection under a given environment would bring about better results in the end. (393) A number of stations have tested and introduced foreign varieties:

GUELPH, CANADA.

JOANETTE.—Imported from France in 1889; panicle spreading; grain black. Where successfully grown produces very large yields of grain. Produces a very short straw. Not suitable for growth throughout the greater part of the Province. Sown very thinly (four pecks per acre) on rich soils, cut a little on the green side, and bound into small sheaves, they bring good results. They are the greatest stooling oats and possess the thinnest hulls (which necessitates caution in threshing) of any so far experimented with. The grain is of excellent quality.

SIBERIAN.—Imported from Russia in 1889; panicle spreading; grain white and of excellent quality; hulls comparatively thin. Produces a long straw and is well suited for medium to poor soil. Appears to have the widest adaptability of any variety raised in the Province and is one of the most popular in Ontario at the present time.

ODERBRUCKER.—Imported from Germany; panicle spreading; grain white, of good quality. Straw not so stiff as that produced by Siberian, and the grain weighs somewhat less per measured bushel.[1]

OTTAWA, CANADA.

TARTAR KING has recently been brought out by Garton Bros., England. It has a stiff straw and a larger percentage of hull than most varieties tested at Ottawa. Color of grain, white. The yield of grain is not so large as with some other varieties, but for rich soil is probably worthy of a trial.

WISCONSIN.

SWEDISH OATS (WISCONSIN NO. 4).—Originated in Sweden; introduced into Finland and Russia, and into the United States from Russia by the Department of Agriculture and distributed to United States Experiment Stations. This station obtained seed (six pounds) in 1899 sufficient to sow one-tenth acre. Its evident good qualities led the station to continue its cultivation two years for seed for the field and for distribution. The variety was more productive than the varieties previously grown. Of thirty-eight different varieties tested for five years at the station, this variety proved the most satisfactory. It likewise gave best results under field conditions during the same period. The Swedish oat has its panicle spreading, grain white. It is noted for its special adaptability to well-drained soils, to soils of poor grade, its strength of culm and its resistance to drought, the last named quality being due to its abundant root development. It has been reported that this variety does not fill well and produced straw too abundantly on rich prairie soil.[2]

[1] Rpt. Ont. Agr. Col. and Expt. Farms, 1901, 1902, 1903.

[2] Wis. Rpt. 1902, p. 219; 1903, p. 265.

NEBRASKA.

KHERSON OATS.—Introduced into Nebraska in 1897 from the Kherson government of Russia. Panicles spreading; grain light yellow; small, but numerous, and having a very thin hull. The growth is vigorous, but not rank, the culm being very short; leaves very broad. In weight per bushel and yield per acre, this variety has led all others at this station. On account of its habit of growth the oat is reported to be peculiarly adapted to central and western Nebraska. A three years' test indicates that it is earlier, yields better, and, excepting the Texas Red, weighs heavier than any other variety. At this station it has proved itself the superior of Texas Red in yield per acre. It is reported as having remarkable drought-resisting qualities. In an experiment in 1902, in which Swedish Select lodged so badly as to make it impossible to determine yield, Kherson oats, though partly lodged, yielded forty-two bushels per acre. Sixty Day, also from Russia, although not lodged, partly shelled, and yielded only thirty bushels per acre.[1]

390. **Crossing.**—The indications are that oats are nearly always self-fertilized. Artificial cross-fertilization is most successfully accomplished on cool, moist days.[2] No American cross-bred variety of oats has as yet been widely distributed.

[1] Neb. Bul. 82 (1904).

[2] E. S. R. XIV, p. 216.

# XIX.

## OATS.

### I. CLIMATE.

391. **Influence of Climate Upon Distribution.**—Oats are naturally adapted to a cooler climate than wheat, barley or maize. North Dakota Station has shown that oats require less number of days and less heat units than spring wheat or maize.[1] The climate needs to be both cool and moist. Oats grow fairly well in the South, where, while warm, it is moist, but in California, where both warm and dry, oats do not do as well as wheat or barley. Oats grow to perfection in the cool, moist, insular climate of Scotland, Norway and Sweden, as well as in Canada. Doubtless the pendant spikelets, with large outer glumes, protect the flowers from cold rains. Oats may be grown as far north as 65° N. Lat. both in America and in Norway, and have matured seed in Alaska where the thermometer reached 30° F. or lower every month in the year.

Barley and oats grown in 1903 at Rampart, Alaska. Latitude 65° N. (O. E. S. Rpt. 1903.)

392. **Influence of Climate Upon Distribution and Yield.**—The relative adaptability of oats compared with other cereals to certain climatic conditions is shown by results of experiments in central Canada and central Ohio. By growing oats, barley, field peas and spring wheat separately and

1 No. Dak. Bul. 47 (1900), p. 704.

in combinations in Canada for six years, it was found that the influence upon yield of grain was in order just given from greatest to least. (404) In Ohio, on the fortieth parallel, the yield of grain for five years when grown continuously on unfertilized soil was as follows:

| | Yield of grain | | Price, ct.[1] | Value |
|---|---|---|---|---|
| | Pounds | Bushels | | |
| Maize . . | 2,957 | 52.8 | 35 | $18.48 |
| Winter wheat . | 1,898 | 31.6 | 65 | 20.54 |
| Spring oats . | 1,014 | 34.8 | 28 | 9.74 |

393. **Influence of Climate Upon Physical Properties of Oats.**—The physical properties of oats seem to be readily affected by climate. The Southern varieties are larger but less dense, less plump, often of a dirty dun color, with long awns, while the Northern grown varieties have shorter, smoother grains, with short awns or awnless. The fact that short, plump, smooth, heavy grains have the largest market value has led to the importation of varieties from Scotland, Norway and Sweden. To what extent these variations are due to selection and to what extent to environment has not been clearly proven; but the Ohio Station has found that during ten years' experiments with seventy-one varieties, the weight per bushel has decreased while the yield per acre has apparently increased.[2] The Oklahoma Station compared fifty varieties of Southern grown seed with thirty-four varieties of Northern grown seed and obtained slightly larger yields of grain and straw from Southern grown varieties.[3] On the other hand, the Ontario Agricultural College

[1] For purpose of computation, average December farm price for decade 1890-1899 was used.

[2] Ohio Bul. 139, p. 45.

[3] Okla. Bul. 16 (1895), p. 36.

and the Missouri Station have been exchanging seed oats yearly, and the results have shown in general that the Missouri grown oats have produced the largest yield of grain, and that the Ontario seed produced grain of the best quality when grown in Ontario.[1]

394. **Need of Water.**—It has already been shown that the water requirement of oats may be large. (391) This has been confirmed by King, who reports the water requirement of a pound of dry matter in oats to be 504 pounds; of barley, 464 pounds; and of maize, 277 pounds.[2] To this must be added the fact that the growth of oats is very rapid and the amount of straw relatively large. The daily demand for water during the period of most rapid growth for each pound of grain produced is high. The amount of water required for irrigating oats in Western States is estimated at about one and three-quarters feet, distributed between May 22 and August 20.[3]

### II. SOIL AND ITS AMENDMENTS.

395. **Soil.**—The character of the soil upon which oats are sown is of less importance than any other cereal, with the possible exception of buckwheat. Almost any tillable soil brings a fair crop if climatic conditions and cultural methods are suitable. It is on this account, and because oats are liable to lodge on fertile soils, that they are sown on the poorer soils and on soils in the most exhausted state of fertility. The oat does best, however, on relatively moist soils.

396. **Rotation.**—The oat appears less influenced by rotation with grass and clover than either wheat or maize. The Indiana Station has grown maize, wheat and oats continuously or in alternation one with another for fifteen years, in comparison with the same crops in rotation with grass and clover on

1 Ont. Agr. Col. and Expt. Farms Rpt. 1903, p. 122.

2 Physics of Agriculture, p. 139.

3 U. S. Dept. of Agr., O. E. S. Bul. 119.

adjacent plats. The average per cent of gain from rotation with clover and grass has been: wheat, fifty; maize, twenty-two; and oats, nineteen.[1] In the American systems of rotation oats usually follow maize. The following may be recommended: For winter wheat sections: maize, one year; oats, one year; winter wheat, one year; timothy and common red clover, one or two years. (119) For sections specially adapted to maize and not to wheat: maize, two years; oats, one year; timothy and clover, one to three years, depending upon live stock kept. (283) For Southern States: maize and cowpeas, one year; oats, followed by cowpeas harvested for hay, one year; cotton, one or two years. In the first year of this rotation, the cowpeas grown between the rows of maize may be harvested for grain. It has been shown that a rotation including cowpeas greatly increased the subsequent yield of oats.[2] In Arkansas it has been found possible to raise a profitable crop of peas after removing a crop of oats, in time to seed to oats again in the fall. When the stubble was plowed under, the subsequent yield of oats was considerably increased, and when the vines also were plowed under, the increased yield of oats was greater than that caused by the application of 400 pounds of a complete commercial fertilizer per acre.[3]

397. **The Influence of Fertilizers.**—Fertilizers are seldom applied to the oat crop, both because they are apt to grow too rank and because it usually pays better to apply the manure to some other crop.[4] Oats, however, respond very readily to an application of fertilizers when applied where needed, as shown in various rotations where light and heavy applications of stable manure and commercial fertilizers were used continuously for ten years.[5]

[1] Ind. Rpt. 1895, p. 38.

[2] Ala. Bul. 95, p. 157.

[3] Ark. Bul. 66.

[4] Ohio Bul. 134, p. 91.

[5] Ind. Bul. 88.

Where oats follow maize which has had an application of stable manure and precede wheat which is to have an application of commercial fertilizers, ordinarily no soil amendment will be required for oats. Where land is seeded to grass and clover with oats, an application of commercial fertilizer may be desirable. Where commercial fertilizers are used, the kind, quantity and method of application will be similar to that for wheat. (122, 123) The relative importance of the several fertilizing constituents is also similar. (121) The Georgia Station recommends the following for Southern conditions: acid phosphate, 200 pounds; muriate of potash, fifty pounds; nitrate of soda, twenty-five pounds; cotton seed meal, 200 pounds to be sown with fall oats, and seventy-five pounds of nitrate of soda to be applied in the spring.[1] At the Pennsylvania Station during twenty years lime increased the straw when used alone or in connection with stable manure, but when used alone caused a decrease in yield of grain.[2] The Rhode Island Station found a marked increase in yield of green fodder by the use of lime.[3]

## III. CULTURAL METHODS.

398. **Seed Bed.**—It is not customary to prepare the seed bed so deep for oats as for wheat, rye, barley or maize. In the North Central States many acres are sown on maize land without plowing. The oats are sown broadcast on the unprepared land and covered with a maize cultivator (312) or disk harrow (299) or similar instrument. Sometimes the unplowed land is cultivated once before sowing the oats and then cultivated once or twice afterwards. Good crops are grown in this way, as shown in the table on page 297, but very much depends upon the nature of the soil, and something upon the season:

[1] Ga. Bul. 44, p. 18.

[2] Penn. Rpt. 1902, p. 191.

[3] R. I. Rpt. 1894, p. 111.

**Results of Different Cultural Methods Compared.**

| Station | Bulletin | Yield of grain (bushels) | | | No. years tested |
|---|---|---|---|---|---|
| | | Fall plowed | Spring plowed | Prepared without plowing | |
| Illinois | 12 | 51.1 | .... | 54.7 | 2 |
| Illinois | 23 | .... | 36.1 | 39.1 | 2 |
| Kansas | 74 | 25.5 | 27.4 | 24.0 | 5 |
| Michigan | 164 | 49.6 | 42.0 | .... | 1 |
| Minnesota | 40 | .... | 79.3 | 82.5 | 1 |
| North Dakota | 11 | 28.6 | 26.0 | .... | 1 |
| Ohio | 138 | .... | 52.8 | 48.7 | 6 |
| Oklahema | 16 | 34.8 | 32.0 | .... | 1 |
| Pennsylvania | Rpt. 1891 | .... | 40.4 | 31.3 | 1 |

Where soil is naturally compact, as shown at Pennsylvania Station, plowing gives better results. Sometimes oats are sown on the uncultivated surface and the land plowed, turning the oats under three or four inches deep. A medium compact seed bed appears to give better results than one either very loose or very compact. While as in other cereals no marked differences are found between fall and spring plowing directly, yet because it enables earlier seeding in the spring and facilitates spring work, fall plowing is to be recommended in most instances.

399. **After Treatment.**—Rolling either before or after oats are up has not materially influenced the yield, although it is often good practice on account of subsequent use of harvesting machinery, particularly if land has been seeded to grass. Where a hard crust has formed after sowing, harrowing or even rolling may serve to break this crust. If land is rolled when too wet, it may so pack the soil as to prevent proper air ventilation and retard germination. The Wisconsin Station has shown that the temperature of a rolled soil may be higher than one that has not been rolled, and the percentage of moisture

slightly decreased.[1] On clay soils heavy rains are more likely to pack the soil unfavorably on rolled than upon unrolled land. On such soil a light harrowing after rolling may prove beneficial. Harrowing after oats are up has increased the yield of grain in Nebraska,[2] but decreased it in Kansas.[3] Oats may be cultivated by sowing two drill rows and missing two, but using the same amount of seed per acre. Sometimes increased yields have been obtained, but usually a decreased yield results from more or less accidental injury to plants. It appears that on gravelly soil especially liable to suffer from drouth, cultivation may increase the yield, but ordinarily it cannot be considered good practice. The Iowa Station found that cutting back oats when showing five leaves decreased the amount of lodging, increased the yield twelve per cent and somewhat delayed ripening.[4]

400. **Influence of Size of Seed.**—The Ohio Station obtained heavy and light seed by use of a fanning mill and during seven years averaged forty-six bushels with heavy seed, forty-five bushels with common seed and forty-three bushels per acre with light seed. No difference was found in weight per bushel.[5] By the same method Kansas Station during eight years obtained thirty-one, thirty and twenty-eight bushels respectively.[6] Minnesota Station sowed two bushels of oats weighing thirty-seven pounds per bushel and two bushels weighing twenty-one pounds per bushel, and obtained sixty-four and fifty-five bushels of grain per acre respectively.[7]

401. **Influence of Seed Selection.** — In the above tests the selection was by specific gravity and not by weight of individual

[1] Wis. Rpt. 1891, p. 91.

[2] Neb. Rpt. 1899, p. 15.

[3] Kan. Bul. 13 (1890), p. 62

[4] Iowa Bul. 45 (1900), p. 220.

[5] Ohio Bul. 38, p. 48.

[6] Kan. Bul. 74, p. 199.

[7] Minn. Bul. 31, p. 201.

seeds, and in each case equal quantity but not equal number of seeds per acre was used. By means of hand selected seeds, and using the same number of seeds per acre, the Ontario Agricultural College obtained during seven years sixty-two bushels with large seeds, fifty-four bushels with medium sized seeds, and forty-seven bushels of grain with small seeds.[1] In the Northwest Territories selected, well cleaned, and small oats for seed yielded 131, 122, and 121 bushels respectively.[2]

402. **Seed Selection.**—In the above experiments the influence of weight or specific gravity of seed upon yield rather than the hereditary influence of continuous selection of seed was determined, a fresh source of seed in most instances being used for each year's work. It should be remembered that every spikelet of oats contains two seeds, one very much larger than the other. In the following experiment by Zavitz the influence of continuous selection of large, plump, well-developed seeds was compared with the like selection of light-weighing and light-colored seeds. At the end of eleven years, the former produced seventy-seven bushels per acre and the latter fifty-eight bushels per acre. An ounce of the former contained 1,208 grains, while an ounce of the latter contained 1,586 grains. The selection of hulled seed continuously showed a tendency to produce oats which were easily hulled during threshing.[3]

403. **Mixing Varieties.**—It has been held that since varieties have different habits of growth, the mixing of two or more varieties might enable them more fully to occupy the soil and thus produce higher yields. During seven years the Ohio Station tested a mixture of four distinct varieties but found no influence upon yield as compared with the varieties not mixed.[4]

[1] Ont. Agr. Col. and Expt. Farms Rpt. 1903, p. 118

[2] Can. Expt. Farms Rpt. 1901.

[3] Ont. Agr. Col. and Expt. Farms Rpt. 1903, p. 119.

[4] Ohio Bul. 138.

404. **Sowing with Other Cereals.**—The Ontario Agricultural College grew oats, spring wheat, barley and peas separately and in eleven combinations for grain and straw during six years. In about ninety per cent of the experiments, the mixtures produced the larger yields of grain, a combination of oats and barley being best.[1] The Ottawa Station found oats alone produced a better yield than a mixture in one location and that the mixture did best in another location and season. The best mixtures were one bushel each of barley, oats and peas, and one-half bushel of spring wheat, one of oats, three-fourths of peas and three-fourths of barley per acre.[2]

405. **Sowing with Field Peas.**—Oats are sometimes mixed with field peas for the production of green or dry fodder for grain. They may be mixed and sown in an ordinary wheat drill, or peas may be sown and the land plowed, covering the peas about four inches deep. Land may then be fitted and the oats sown broadcast or with drill. Sowing the oats may be delayed for about a week to give the peas a start of the oats. This mixture is frequently sown for soiling milch cows where pasture is restricted or not available. By sowing at different dates a succession of green fodder may be had as follows in the North Atlantic and North Central States, allowance being made for soil and season:

| Time of seeding | Time of cutting |
|---|---|
| March 20-April 1 | June 1-20 |
| April 1-20 | June 15-July 5 |
| April 20-May 10 | July 1-July 25 |

The Vermont Station secured 10,917 pounds of water-free substance containing 12.6 per cent of protein by growing peas and oats for fodder, and found this mixture superior to oats and spring vetch (*Vicia sativa* L.).[3] Zavitz found in Ontario,

1 Ont. Agr. Col. and Expt. Farms Rpt. 1898, p. 144.

2 Can. Expt. Farms Rpt. 1900.

3 Vt. Rpt. 1895, p. 195.

Canada, as a result of five years' tests, that Daubeney oats and Chancellor peas yielded 5.9 tons of green fodder in seventy days; Siberian oats and Prussian Blue peas 6.9 tons in seventy-seven days; and Mammoth Cluster oats and Prince Albert peas 6.1 tons in eighty-four days from time of seeding. Two bushels of Siberian oats and one bushel of Prussian Blue peas are recommended for the production of either green fodder or dry fodder.[1] Hays found both in North Dakota and Minnesota that oats and field peas sown separately produced a better yield of grain than a mixture.[2]

406. **Oats and Rape.**—By sowing one pound of rape seed with six pecks of oats the Iowa Station produced sixty bushels of oats, while in October the rape produced eighteen tons of green substance per acre.[3] In order to avoid interference with harvesting oats, rape should be sown two to three weeks later than the oats. The rape may be pastured or plowed under as green manure.

"There is no doubt but that the first step in the economical use of phosphates is to imitate nature and endeavor to keep the soil well supplied with organic matter; for it is only by such means that the phosphates contained in the soil naturally and those applied artificially can be fully utilized by the cultivated crops.

"It is very evident from all the tests cited that some crops, particularly the turnip family, have a greater ability than others to use crude or insoluble phosphates, and these experiments would certainly teach that the aim should be to employ such crops for rendering insoluble phosphates available, and by such a practice save much that is now being spent for sulphuric acid and the cost of manufacturing the soluble phosphates."[4]

407 **Treatment of Seed.**—All seed oats should be treated for loose smut. (415) The same methods may be employed that are recommended for stinking smut on wheat, the formalin treatment being the most commonly used. (149) The solution

[1] Ont. Agr. Col. and Expt. Farms Rpt. 1901, p. 99.

[2] No. Dak. Bul. 10 (1893), p. 44, and Minn. Bul. 20 (1892), p. 35.

[3] Iowa Bul. 45 (1900), p. 216.

[4] H. J. Patterson, in article on Phosphates, Penn. State Dept. of Agr. Bul. 94.

may be sprinkled over the oats, the grain being stirred meanwhile, when one gallon of the solution will be sufficient for four bushels of oats; or the oats may be placed in gunny sacks and submerged in the liquid for ten minutes. The sacks are then allowed to drain for several minutes, when the oats are spread out to dry. In this case more liquid will be required.

408. **Rate of Seeding.**—The rate is not materially modified by the thickness of seeding within certain limits. The oat plant, like the wheat plant, has the ability to adapt itself to its surroundings, so that where it is thinly planted it stools more than where thickly planted. On some soils, at least, the thinly sown oats are later in maturing, and the proportion of straw is greater. No definite rule can be laid down, but sowing from two to three bushels, according to fertility of soil, preparation of seed bed, manner of seeding and size of seed may be taken as a safe guide for spring sowing in Northern States. The number of seeds in a pound of oats has been found to vary with different varieties from about 11,000 to about 30,000. The following table shows the rate of seeding per acre which gave the most satisfactory results at the several stations indicated:

**Rate of Sowing in Pecks per Acre.**

| Station | Bulletin | No. years' test | No. pecks |
|---|---|---|---|
| Illinois | 41 | 6 | 10 |
| Indiana | 50 | 8 | 8 |
| Kansas | 74 | 7 | 16 |
| Kentucky | 23 | 1 | 8 |
| Minnesota | 40 | 1 | 9 |
| North Dakota | 39 | 2 | 9 |
| Ohio | 138 | 5 | 9–10 |
| Pennsylvania | Rpt. 1891 | 1 | 14 |
| South Dakota | 17 | 1 | 12 |
| Utah | 56 | 3 | 8 |

**409. Time of Sowing in Southern States.**—In sowing winter varieties in the Southern States the best results are usually obtained by sowing between October 1st and November 15th. Not infrequently, however, the seeding is delayed until December. In the South the so-called spring seeding may take place in January, February and March, according to location, February being generally best.

"The rule of sowing in the 'twelve' days following Christmas day never haa any basis in sound reason, and it is believed to be about the most inauspicious time that could be hit upon, it being generally the very coldest period of winter."[1]

It is believed to be good practice to reserve a few acres for spring seeding in case the fall sown oats are winter killed. If not winter killed this smaller area is sown to a spring variety; if winter killed the larger area is sown to a spring variety and the smaller area to a winter variety in order to secure seed again.

| Station | Bulletin | No. of seasons | Earliest | Best | Latest |
|---|---|---|---|---|---|
| Ont. & Quebec | Cen. Expt. Farm 21 | 5 | Apr. 13-22 | Apr. 13-22 | May 18-June 12 |
| Maritime Prov. | " | 4 | Apr. 27-30 | Apr. 27-30 | June 1-13 |
| Manitoba . | " | 3 | Apr. 23-May 2 | May 7-9 | May 30-June 5 |
| Northwest Ter. | " | 4 | Apr. 6-24 | Apr. 27-May 16 | May 11-29 |
| Brit. Columbia | " | 4 | Apr. 12-24 | May 17-25 | May 17-29 |
| Illinois . | 41 | 5 | March 15 | Mch. 28 Apr. 8 | May 10 |
| Kansas . | 74 | 5 | March 1 | March 9-16 | May 3 |
| Kentucky . | 23 | 1 | March 22 | March 22 | April 12 |
| Minnesota . | 40 | 1 | April 22 | April 27 | May 7 |
| Pennsylvania | Rpt. 1891 | 1 | April 8 | April 8-15 | May 6 |
| Utah . | 56 | 4 | April 22 | April 22 | June 1 |

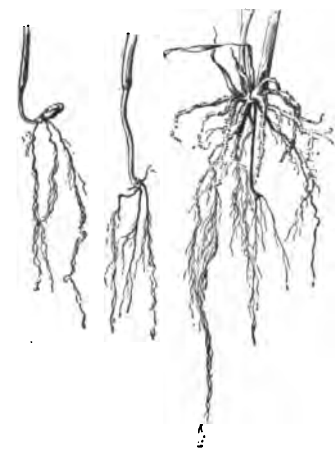
**410. Time of Sowing in Northern States.**—Since oats require a moist, cool climate for their best development, they should be sown as early in the spring as possible. Experiments indicate that there is a marked decrease both in yield and the weight per bushel when the seeding is delayed. With maize the time

[1] Ga. Bul. 44, p. 10.

of planting, within four or five weeks during any season, is not especially important. Such a difference in time of sowing oats may make the difference between success and failure. The table on page 303 shows the best dates as determined at the stations indicated, as well as indicating the period of the tests.

411. **Depth of Sowing.**—The depth of sowing between one to four inches does not materially influence the yield, although the best results have been obtained with sowing from one to two inches, as shown in the following table:

| Station | Bulletin | No. years tested | Depth, inches |
|---|---|---|---|
| Illinois . . . . . | 41 | 6 | 1 |
| Kentucky . . . . . | 23 | 1 | 2 |
| Minnesota . . . . . | 40 | 1 | 1 1-2—2 1-2 |
| Ohio . . . . . | 101 | 4 | 1—2 |

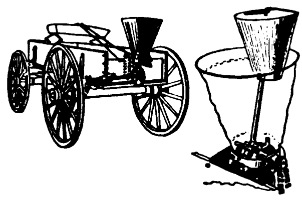


Wheat roots, showing that the depth of the permanent roots is not influenced by the depth of seeding. In the plants on the left the permanent roots will arise at the point where the culm enlarges. (About one-fourth natural size.)

The same principles apply here as with maize and wheat. (130, 300)

412. **Methods of Sowing.**—Unless the land is plowed, oats must, of course, be sown broadcast. On plowed land the practice is divided, but broadcasting is probably the most general, the controlling reason being that they can be somewhat more cheaply sown in this way than if the drill is used. The experimental evidence does not clearly indicate any increase in yield from either method, much apparently depending upon soil, season, preparation of seed bed, depth of seeding, and quantity of seed used. If drouth prevails

at or just after seeding, or soil is of a character to suffer from dry weather, drilling would be preferred. If drilling is accompanied by better preparation of seed bed, it is to be preferred. Broadcasting requires more seed, perhaps a half bushel to the acre more, much depending upon the preparation of the seed bed. The same seeding machinery described for sowing wheat may be used for oats. (135) The broadcast seeder attached to the end gate of a wagon is widely used where oats follow maize without plowing. Kansas Station found during seven years an average of twenty-six bushels by broadcasting and thirty bushels by drilling. Slightly better results have been obtained by using the shoe drill with press wheels than by the shoe drill without press wheel or by hoe drill.[1]



Broadcast seeder attached to the end gate of farm wagon and driven by rear wheel. Drawing on the right shows hopper with grass seed attachment.

413. **Method of Fall Sowing.**—The Georgia Station recommends the following method to prevent winter killing:

"On the station farm we have found, even when the drills were laid two feet or one and a half feet apart, using a common scooter plow, or, better, a single-row fertilizer and seed distributer—that oats so sown always produce a larger yield than when sown broadcast and harrowed in. But a more important discovery is the fact that when the seed are sown in open furrows and barely covered, leaving the furrows open or unfilled, the oat plants are very much less liable to be killed by a severe freeze. The idea was conceived several years ago, and annually since we have sown the larger portion of the fall-sown area in drills eighteen to twenty-four inches apart, latterly using a Gantt fertilizer distributer. This sows but one row at a


Grain and fertilizer drill recommended by Georgia Station for fall seeding of oats. The covering attachments, *a*, are removed when sowing oats.

1 Kan. Bul. 74, p. 200.

time, has no covering attachment, but simply opens a small furrow and sows the seed. The result is the plants come up one and a half to two inches below the general surface, and the 'crown' of each plant is formed and established say two to two and a half inches below the general surface. The winter rains, light freezes and thaws gradually but only partly fill in the open furrow, and the more vital and sensitive parts of the plants are left at the original depth, below the reach of even very severe freezes."[1]

## IV. WEEDS, FUNGOUS DISEASES AND INSECT ENEMIES.

Homemade spraying apparatus for killing wild mustard; also used for spraying potatoes.

Loose smut on oats. Glumes more fully destroyed in specimen on the right.

414. WEEDS.—The oat, like all other spring sown cereals, is apt to be infested with any weeds whose seeds happen to be present in the soil. Weeds are frequently a hindrance to the proper curing of the crop. In the Northern States the most conspicuous weed in the oat crop is the wild mustard, which may be eradicated by spraying the oats with a three per cent solution of copper sulphate at the rate of fifty gallons of the solution per acre. (144)

415. FUNGOUS DISEASES.—The oat plant is generally exceptionally free from insect enemies and fungous diseases. Besides the two species of rust occurring upon wheat (146) there occurs also on oats crown rust (*Puccinia coronata* Cda.), so called from the horn-like projections on the teleutospores. No remedy is known. There are two forms of smut, namely, loose smut (*Ustilago avenae* (Pers.) Jens.) and covered smut (*Ustilago avenae laevis* (Jens.) Kell. and Swing.). The first form, which is most common, converts the entire spikelet into smut spores, while in the second only the kernel is so affected. Both are successfully prevented by treating with hot water or formalin. (149) A bac-

[1] Ga. Bul. 44 (1889), p. 11.

terial disease sometimes causes the death of the lower leaves and more or less yellowing of the young plants.[1] No remedy has been discovered.

416. INSECT ENEMIES.—There is no insect which confines its attacks to the oat plant, and aside from the chinch bug (151), grasshoppers and fall army worm, there is none that causes extensive and serious damage to the growing plant. (153) The stored grain is less seriously attacked, doubtless on account of its hull.

[1] Journal of Mycology, Vol. VI, p 72.

# XX.

## OATS.

### I. HARVESTING AND USES.

417. **Time and Method of Harvesting.**—The evidence appears to be that oats may be cut when one-half the leaves are still green and the grain in the early dough, without materially injuring the chemical composition or the yield of grain, and that the yield and quality of the straw may be increased provided the sheaves are immediately shocked and capped to permit slow curing and ripening.[1] (161) Cutting in the hard dough stage and slow curing in round shocks is generally desirable, but when weeds abound or for other reasons rapid curing is necessary, long shocks are better. Oats may be cut for hay while the grain is in the milk stage with mowing machine and treated as any other hay crop, or may be cut with self-binding harvester and put in round shocks of six bundles each, with one bundle for a cap. The methods of harvesting, threshing and storing of oats are similar to those of wheat. (162, 167, 168, 169) The Ohio Station found the shrinkage of grain between September and March of fifty-five varieties to be less than one per cent, and of a sample of baled oat straw during the same period about six per cent.[2] Michigan Station obtained similar results with the grain two years, and a loss of three per cent another year.[3]

418. **Uses.**—Oats are the chief grain food for horses, and are equally acceptable to and desirable for cattle and sheep, but

1 Ill. Bul. 31; Kan. Buls. 13, 29, 54.

2 Ohio Bul. 57 (1894), p. 111.

3 Mich. Bul. 191 (1901), p. 169.

are not as largely used for these classes of live stock because of the relatively high price as compared with other concentrates. They are not adapted to swine, because of their high percentage of crude fiber due to the hull. Oats are used largely in connection with and interchangeably with maize. If one is more plentiful, and, therefore, cheaper than the other, it is used more abundantly. Hence in considering the possibility of a rise or fall in price of either, the combined yield of the two cereals must be ascertained. In the Southern States, where it is difficult to grow our tame grasses for pasturage and hay, special varieties have been developed for this purpose. (387) When cut in the milk and properly cured they make a palatable and nutritious food for domestic animals. (383)

Oat straw is preferred to wheat and rye straw as food for cattle and sheep, and by some for bedding, although it will not last as long, hence is less generally purchased for this purpose. It is less valuable than either for the manufacture of paper.

419. **Oats for Human Food.**—As prepared for human food, they are the most nutritious of our cereals. The consumption of oatmeal has increased enormously in recent years, and has led to the introduction of many other forms of so-called breakfast foods. Oatmeal is especially adapted to people living in northern climates or those having plenty of outdoor exercise. It is said that in eastern Scotland the unmarried plowmen lived solely on oatmeal and milk, except in the winter, when they sometimes got potatoes. They were allowed seventeen and one-half pounds of oatmeal weekly, and three to four pints of milk daily. This formed their sole diet, with no other cooking than boiling water stirred into the meal. These men were strong and healthy. The witty Dr. Johnson sarcastically remarked: "Oats is a grain fed to horses in England, but eaten by men in Scotland." "Yes," said a Scotchman, "and I have noticed that they grow the best of horses in England and the best of men in Scotland."

420. **By-Products.**—About the only manufacturing industry based upon the oat grain is the oatmeal industry, and about the only by-product is the hull. Oat hulls are largely used to adulterate maize meal, when it frequently passes for maize and oatmeal under the name of corn and oat feed. These oat hulls have but little food value. (383)

### II. PRODUCTION AND MARKETING.

421. **Oat Crop of the World.**—The production of oats in the world has varied during the five years 1898 to 1902 inclusive from 2,806 millions (1901) to 3,561 millions (1902) per annum, the average annual production being 3,131 million bushels. The following table shows the average annual production for five years by continents in million bushels:

| | 1898-1902 |
|---|---|
| Europe | 2,103 |
| North America | 944 |
| Asia | 52 |
| Australasia | 25 |
| Africa | 7 |
| Total | 3,131 |

The production exceeds wheat and about equals maize in bushels but is less than either in pounds. The production in bushels of oats in Canada is about twice that of wheat. Ontario produces more oats than any State of the United States except Illinois and Iowa. Oats are only sparingly cultivated in South America.

422. **Oat Crop of the United States.**—Oats stand third in acreage and value of product and second in number of bushels of the cereals of the United States. The annual production for the three decades, 1870-79, 1880-89 and 1890-99, is given as follows:

**Yield and Value of Oats for Three Decades.**

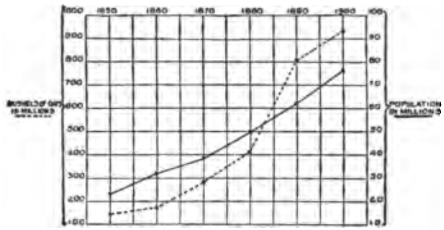
| | 1870-79 | 1880-89 | 1890-99 |
|---|---|---|---|
| Area, acres | 11,000,000 | 22,000,000 | 27,000,000 |
| Yield, bushels | 314,000,000 | 584,000,000 | 695,000,000 |
| Value, dollars | 111,000,000 | 181,000,000 | 189,000,000 |
| Value per bushel, dollars | 0.35 | 0.31 | 0.28 |
| Yield per acre, bushels | 28.4 | 26.6 | 26.2 |
| Value per acre, dollars | 10.00 | 8.22 | 7.34 |

About one-tenth the area in field and garden crops, not counting pasture, is in oats, thirty-seven per cent of the farms reporting this crop. The value per acre is less than any other important cereal crop and like other cereals is decreasing in value. Ten States produced eighty per cent of the oat crop in 1900, all but New York and Pennsylvania being North Central States. Probably three-fourths of the oats of the United States are produced north of the fortieth parallel and east of the 100th meridian.

423. **Yield per Acre.**—The average annual yield per acre of oats during the decade 1893-1902 was 27.8 bushels. The areas of maximum production per acre in 1899 embraced the northern parts of Ohio, Indiana and Illinois and parts of Michigan, Wisconsin, Minnesota and Iowa, the yield being more than thirty-six bushels per acre. The yield per acre in the South Atlantic division was less than ten bushels over nearly one-half the area, and with a few exceptions did not exceed twenty bushels. Sixty to seventy-five bushels of oats is considered a good yield and forty to fifty bushels a fairly satisfactory yield in the Northern States. In Canada the yield per acre is considerably higher than in the United States, 100 bushels per acre being frequently reported.

424. **Progress of Oat Production.**—The production of oats has about doubled in proportion to population during the last half of the century. The production rose between 1880 and

1890 from about 400 million to 800 million, the most phenomenal increase in the production of any crop in America at any period.



Relative increase in the population and in the production of oats in the United States during a half century.

425. **Center of Production.**—The center of production of oats has shifted westward and northward, as is shown by the fact that while New York, Pennsylvania and Ohio were the center of the crop in 1850, now (1900) the concentration is in Illinois, Iowa and Wisconsin. This represents a movement in the last half century of a little less than 120 miles northward (to 41° 39′ 15″ N. Lat.) and about 575 miles westward (to 91° 8′ 11″ W. Long.). This shows a northward movement of oat production twenty-one miles more than of wheat and 115 miles more than of maize, while the westward movement has been ninety-five miles more than of maize and 105 miles less than of wheat.

Map showing the production of oats in the United States in 1900.

The increasing use to which maize is being put as feed for milch cows is largely responsible for the relatively decreased area devoted to oat production in some States, as is shown by the fact that the majority of the States which reported decreased acreages in oats reported increased acreages in maize. These States were principally in the dairy sections.

426. **Export of Oats.**—The quantity of oats exported is small compared with wheat or maize, although increasing relatively

more rapidly than either. The export of both grain and oatmeal has about trebled during five years, while wheat and maize have about doubled. (189, 364) The principal importers of grain are Great Britain and South Africa; and of oatmeal, Great Britain, Germany, Netherlands and South Africa.

427. **Commercial Grades.**—The Illinois Board of Railroad and Warehouse Commissioners recognizes the following classes and grades of oats:

White oats, Nos. 1, 2, 3 and 4.
White clipped oats, Nos. 1, 2 and 3.
Oats, Nos. 1, 2, 3 and 4.

In the Chicago market much the larger proportion of oats dealt in are white oats, and usually more of No. 3 than No. 4, more of No. 4 than No. 2, while seldom does a car grade No. 1. The following are the rules for grading white oats:

"No. 1 white oats shall be white, sound, clean, and reasonably free from other grain.

"No. 2 white oats shall be seven-eighths white, sweet, reasonably clean and reasonably free from other grain.

"No. 3 white oats shall be seven-eighths white, but not sufficiently sound and clean for No. 2.

"No. 4 white oats shall be seven-eighths white, damp, badly damaged, musty, or for any other cause unfit for No. 3."

The rules for white clipped oats are identical for similar grades, except No. 1 white clipped oats must weigh thirty-six pounds; No. 2, thirty-four pounds, and No. 3, twenty-eight pounds to the measured bushel, while white oats are not graded by weight. The rules for grading oats are identical with those for white oats, except where color is indicated it reads "mixed oats."

## III. HISTORY.

428. **History.**—While the origin of the cultivation of wheat can be traced with some probability to a warm climate, and that of rye to a cold climate, oats we find occupying an intermediate position. They were not cultivated by the ancient Egyptians

or the Hebrews, as was wheat. Neither the ancient Greeks nor the ancient Romans cultivated them. They were likewise unknown to the ancient Chinese or the people of India.

All evidence points to eastern temperate Europe, and possibly Tartary, in western Asia, as the probable place of their first cultivation. They were cultivated by the prehistoric inhabitants of central Europe, but did not appear, it is believed, until long after wheat and barley. Hence they were less important in the early history of our race than either of the last named crops or rye. When central and northern Europe became civilized the cultivation of oats became vastly more important, becoming in some of the cool, moist climates north the most important cereal used for man's food. In Scotland it occupies one-third the land in cultivated crops, excluding land in pastures and meadows. In Ireland it constitutes one-half of all the grain and green crops.

## Practicums.

429. METHOD OF CROSS-FERTILIZATION.—Cross-fertilization in oats may be effected in a manner similar to that of wheat. (196) Remove all spikelets of the panicle which are not to be crossed and remove the upper flower of the remaining spikelet and cross the lower one.

430. PLANT IN THE FIELD.—Each student should be given a printed or typewritten sheet, as indicated below, and requested to describe two or more varieties of oats growing in the field by underscoring the adjective which most nearly applies to the condition found.

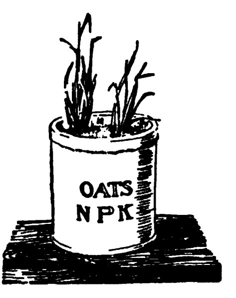
1. Height of culm: average of ten culms to tip of outer glume on upper spikelet . . .
2. Vigor of plant: strong; medium; weak.
3. Diameter below panicle: average of ten culms . . .
4. Depth of furrow below panicle: furrowed; medium; smooth.
5. Upper part of culm: solid; semi-solid; hollow.
6. Wall of culm: thick; medium; thin.
7. Color of culm: light yellow; yellow; bronze.
8. Foliage: scanty: medium; abundant.
9. Rust: leaves, per cent . . .; culms, per cent . . .
10. Smut: per cent . . .
11. Panicle: open; partly closed; closed.
12. Flowering glumes: beardless; partly bearded.

13. Beards: long; medium short; straight; twisted.
14. Color of leaves: light green; medium green; dark green.
15. Leaf blade: average length of ten blades . . .
16. Leaf blade: average width of maximum dimensions of ten blades . . .
17. Leaf blade: erect; ascending; drooping.
18. Leaf blade: smooth; rough; downy.
19. Ligule: large; medium; small.

431. MATURE DRIED PLANT IN LABORATORY.—Proceed as in paragraph above. If opportunity to study varieties in the field is lacking, some of the items above may be included here. If only a field practicum is desired, some of the items below may be included above.

1. Length of panicle: average of five panicles from base of lower whorl to tip of flowering glume of upper spikelet . . .
2. Number of whorls: average of five panicles . . .
3. Number of main branches: average of five panicles . . .
4. Number of spikelets: average of five panicles . .
5. Variation in length of pedicel: . . . to . . .
6. Number of grains: average of five panicles . . .
7. Number of grains per spikelet . . .
8. Weight of grains: average of five panicles . . .; weight per 100 grains . . .
9. Relative size of lower and upper grains of spikelet: weight of twenty-five lower grains . . .; weight of twenty-five upper grains . . .
10. Per cent of kernel: weight of 100 grains . . .; weight of 100 kernels . . .; per cent . . .
11. Plumpness: plump; medium; inflated.
12. Flowering glume: thick; medium; thin.
13. Length: twenty-five grains from base to tip of flowering glume . . .; twenty-five kernels . . .
14. Density: weight per bushel obtained by weighing one pint . . .
15. Color of grain: light yellow; yellow; gray; reddish brown; black.

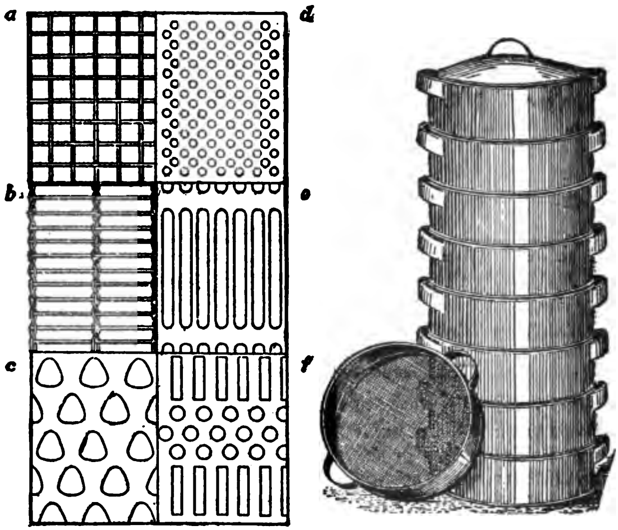
432. SOIL FERTILITY IN RELATION TO OATS.—Provide each student with ten three-gallon earthen jars, which each may fill with earth secured from home farm or elsewhere. Make application of plant food as follows:




1. None.
2. Nitrogen.
3. Phosphorus.
4. Potassium.
5. None.
6. Nitrogen and phosphorus.
7. Nitrogen and potassium.
8. Phosphorus and potassium.
9. Nitrogen, phosphorus and potassium.
10. None.

Nitrogen may be obtained by applying sixteen grams of dried blood or twelve grams of nitrate of soda; phosphorus by applying twenty-four grams of acid rock phosphate or dissolved boneblack; and potassium by applying four grams of potassium chloride. The fertilizers should be thoroughly mixed with the soil to a depth of six inches.

433. Influence of Size of Seed on Early Stages of Plant Growth.—Divide sample of oats into large, medium and small grains. This may be done by hand selection or by means of a nest of sieves. Obtain weight of fifty grains of




On the right, a nest of sieves for cleaning seeds; on the left, sieves with holes of various sizes, forms and positions. For further information see U. S. Dept. of Agr. Yearbook 1894, p. 406.

each and plant under similar conditions either in the field or in the plant house, taking care to cover the seeds a uniform depth. If in pots or trays in pot house, the soil can be removed more easily from the roots.

Note time required for plants to come up and number of plants produced. Obtain average height at end of each week. At end of three or four weeks, depending upon growth, obtain fresh and water-free weight of each lot of seedlings. Make sketches of the more important differences in roots and leaves of the different lots, if any.

434. Influence of Treatment of Seed Upon Germination.—Having carefully graded a sufficient quantity of oats, treat fifty grains each of the following ways:

1. Nothing.
2. Immerse in water at 70° F. for four hours.
3. Immerse in water at 70° F. for ten minutes.
4. Immerse in water at 133° F. for ten minutes.
5. Immerse in water at 70° F. for forty hours, and then at 70° F. for five minutes
6. Immerse in one-fourth per cent solution of formalin for thirty minutes.
7. Immerse in one-half per cent solution of formalin for thirty minutes.
8. Sprinkle with No. 6 solution without immersing.
9. Immerse in two per cent solution of copper sulphate for ten minutes.
10. Nothing.

After treatment all lots are to be dried as much as they would need to be in order to be sown in a grain drill. Place in germinator at 70° F. and determine the number of seeds which have germinated at the end of twenty-four hours for five days. (475) Lots of seed may also be grown as in (433).

435. Collateral Reading.

The Leading Cereal Crops in Canada. By Wm. Saunders. Experimental Farms Rpt. 1903, pp. 6-33.

Farm Manure. By A. Hebart. E. S. R. V, pp. 139-158.

Origin of Cultivated Plants. By A. De Candolle. New York: D. Appleton & Co. (1902), pp. 373-376.

# XXI.

## BARLEY.

### I. STRUCTURE AND COMPOSITION.

436. **Relationships.** — Barley (*Hordeum sativum* Jensen) belongs to the same tribe as wheat and rye, and differs from both in that the spikelets are one-flowered, and in having more than one spikelet at the joint of each rachis.

437. **The Plant.**—Aside from the spike, the barley plant has much the same appearance and habit of growth as wheat. Usually the culms are not so tall, and are perhaps more variable on account of environment. Wisconsin Station found with several varieties during five years an average of one pound of straw for each pound of grain, there being considerably less straw than is usually obtained with wheat or oats.[1] In a comparative trial the proportion of top to root in weight of dry matter was 3.3 to one in barley and 2.2 to one in oats.[2] The indication is that it is more shallow rooted than wheat, maize or oats. Although the roots grow rapidly, they are comparatively feeble and short lived.

438. **The Inflorescence.**—The spikelets are one-flowered, sessile, thus forming a spike. The outer glumes are almost awl-shaped, three-eighths inch long with flexible beard one-half to three-fourths inch long. Flowering glume, which with palea is adherent to fruit, is prolonged into a stiff beard six to eight inches long with strongly barbed edges, making barley a disagreeable crop to handle, although the objection to the beards

[1] Wis. Rpt. 1903, p. 268.

[2] Wis. Rpt. 1892, p. 119.

has been considerably lessened by the introduction of the self-binding harvester, and in the Western States by the header and combined harvester and thresher. As there are three spikelets at each joint of the rachis, each joint bears six outer glumes. There are three stamens and a double feathery stigma similar to wheat. In the six-rowed type there are three spikelets at each joint of the rachis, and these joints are close together, thus forming a square, rather compact spike, which may be four or six-rowed, depending upon whether or not the side rows overlap.

439. **The Grain.**—The barley kernel, like the oat kernel, remains enclosed, except in hull-less varieties, in the flowering glume and palea, from which it is with some difficulty removed. These parts are called the hull, sometimes the husk. In this book the caryopsis of the barley will be called the kernel, and the kernel plus the hull will be called the grain. (388) Although the grain of barley is quite different in appearance from a grain of wheat, when the hull is removed the resemblance is quite close, having like wheat a deep furrow on the side opposite the embryo. It is somewhat broader, with sides more rounded and upper end more pointed.

Selected grains of barley, natural size
(After Hicks and Dabney.)

Barley grains are a little wider than thick, varying from one-fifth to one-tenth of an inch in width, one-seventh to one-twelfth of an inch in thickness, and from one-fourth to one-half of an inch in length. The word barleycorn is sometimes used as a measure of length, meaning one-third inch. The weight of 100 grains varies from 2.5 to five grams, the average being about 3.5 grams, or about 1,300 grains to the pound. In the six-rowed barley the lateral grains are slightly smaller than the central ones. Two-rowed varieties have plumper and longer

grains than six-rowed varieties. Grains coming from the Rocky Mountain and Pacific Coast States are likewise longer and plumper than those from the North Central and North Atlantic States.

440. **The Hull.**—The hull or husk of barley may constitute less than ten per cent or as much as twenty-five per cent of the grain. The average is probably about fifteen per cent, or half that of the oat grain. Grains of the six-rowed barley have thicker hulls than the two-rowed barley. The hull of barley is of value in the process of malting by protecting the embryo during germination and subsequently acting as a filter when the malt is extracted. The rudiment of the second flower is attached at the base of the flowering glume and lies almost concealed in the furrow next the palea. This feathery appendage about half the length of the grain is said to be a ready channel for the conveying of moisture to the kernel.

441. **The Character of the Endosperm.**—The endosperm varies in texture (not structure) and color from mealy white to glassy or vitreous. (238) The character of the endosperm varies with (1) the variety, the two-rowed being more mealy than the six-rowed; with (2) the maturation, fully but not overripe grains being the most mealy; and with (3) the climate, a moist and insular climate being most conducive to complete maturation. (74) As in wheat and maize, a glassy or translucent endosperm is accompanied by high percentage of protein and a corresponding decrease of starch. The character of the endosperm may be determined by cutting the grain across with a sharp instrument. In an average of thirty-six samples of American barley, Wahl and Henius report sixteen per cent of the grains mealy; fifty-two per cent half glassy, and thirty-two per cent glassy. The character of the endosperm may also be determined by placing the grains of barley by suitable contrivance between the observer and a strong light, when the number of opaque, partly opaque and translucent grains may be determined.

442. **The Embryo.**—The embryo is very similar to that of wheat. On account of the plumule becoming twisted upon germination it is known as the acrospire. For good malt the acrospire should be three-fourths the length of the grain, and the radicle or root should be twice that length.

443. **Composition.**—Barley grain is more carbonaceous than either wheat or oats. The grain has more crude fiber on account of its hull; otherwise its proximate composition is very similar to wheat. An analysis of hulled barley is almost identical with that of wheat. Barley differs principally from maize in having a less per cent of fat and higher per cent of crude fiber. Oats contain about three times as much crude fiber as barley; yet the hull of barley is so tough that it is essential to grind it before feeding it to domestic animals, while this is not necessary with oats.

Barley also has less fat and more starch, the starch taking the place of the extra crude fiber in the oats. Barley straw is similar to wheat straw, and barley hay has more protein and less crude fiber than timothy hay. No summary of comparative analyses of American grown two-rowed and six-rowed varieties has been reported. Wahl has reported a two-rowed variety (Chevalier) grown in Montana containing 9.23 per cent of protein and a six-rowed variety grown in Minnesota with 15.16 per cent protein.[1]

444. **Weight per Bushel.**—The legal weight per bushel in Canada and most of the States is forty-eight pounds. A variation from forty-five to fifty pounds is to be found in other States. Variations in weight of measured bushel from forty-two to sixty-eight pounds have been recorded. Variations between forty-five to fifty-five pounds are not uncommon. Hull-less barley usually weighs about sixty pounds to the bushel. The weight per bushel depends much upon the thoroughness with which

[1] R. Wahl: High or low albumen content in barley malt?

the beards are removed. In order to accomplish the thorough removal of beards, the grain is sometimes put through the threshing machine a second time. At elevators where much barley is shipped special machinery is used for thoroughly scouring and cleaning it.

High weight per bushel has been shown to be associated with high weight per grain and consequently, other things equal, greater yield. Other things equal, high weight per bushel indicates low percentage of protein and high percentage of kernel to grain; because (1) starch has a higher specific gravity than protein, and (2) kernel has a higher specific gravity than hull.

445. **Qualities for Malting.**—The ability to germinate completely, quickly and uniformly are essential qualifications for malting. Uniform ripeness, uniform size and purity of variety aid uniformity of germination. The two-rowed and six-rowed varieties must not be mixed, since the plump grains of the former take longer to germinate than the thinner grains although thicker hulls of the latter. Barley should be free from impurities, should not have broken grains or be threshed too short.

"A good brewing barley should have a thin, clean, wrinkled husk, closely adhering to a plump, well fed kernel, which, when broken, appears white and sweet, with a germ full and of a pale yellow colour. The specific gravity being between 1.280 and 1.333, and weighing from 53 to 58 pounds[1] per bushel."[2]

The European maltsters almost universally prefer a mealy endosperm rather than a glassy one. The higher percentage of protein decreases the percentage of starch and this lowers the percentage of malt extract. In addition to this, the higher percentage of protein causes a larger percentage of protein in the beer. Some of the protein compounds are insoluble at high and low temperatures but are soluble at ordinary temperatures. When beer is placed upon ice these protein

[1] Imperial bushel, 2,218.2 cu. in.; United States Standard (Winchester) bushel 2,150.42 cu. in.

[2] Quoted in Can. Expt. Farms Rpt. 1895, p. 231.

compounds are precipitated, causing a hazy appearance in the beer which is not desired, particularly when bottled. It is now claimed, however, that during the process of beer making these insoluble proteids may be changed into soluble proteids if proper conditions are offered, by a peptonizing enzyme which occurs naturally during the process of malting barley. The conditions which favor the development of the enzyme are time and temperature. The longer the growth of the malt and the lower the initial mashing temperature, the more fully will the insoluble proteids be made soluble and the more readily will the remaining insoluble proteids be precipitated by cold storage.

446. **Germination.**—The maximum, minimum and best temperature of the germination of barley is practically identical with that of wheat. Saunders tested the viability of two varieties of barley during six years as follows: 97; 91; 79; 36; 20; 8.[1] Todaro found the germination of barley to decrease in four years from eighty-seven to fifty-eight per cent.[2] The vitality of barley is easily injured by heating in stack or bin. In practice, barley that is more than two years old is not considered safe for malting purpose, but its germinating power increases for a few months after threshing, especially if it has not been stacked. A distinction is made between germinative capacity and germinative energy. The former is its capacity to germinate irrespective of time, and should not be below ninety-five per cent; while germinative energy is the ability to germinate within a definite time, and should not be below seventy per cent at the end of two days or ninety per cent at the end of three days at a temperature of 80° F.

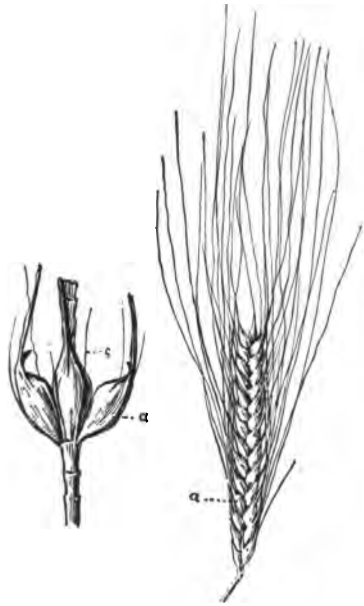
## II. VARIETIES.

447. **Species.**—There are two well-marked types of barley: (1) six-rowed barley (*Hordeum sativum hexastichon* Hackel),

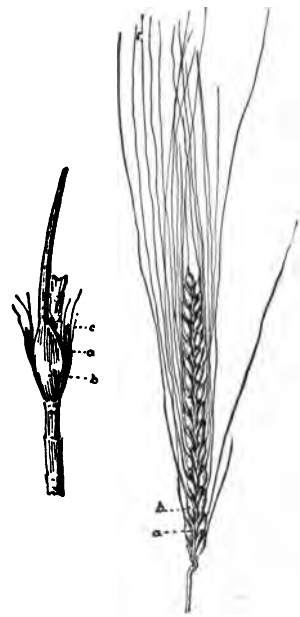
[1] Can. Expt. Farms Rpt. 1903, p. 44.

[2] Staz. Sper. Agr. Ital. 31 (1898), No. 6, pp. 525-563. E. S. R. XI, 157.

and (2) two-rowed barley (*H. sat. distichon* Hackel). In the six-rowed type there are three spikelets each bearing a single grain arranged alternately at each joint of the rachis, thus making a spike with six rows of grains. When the lateral or outside grains of the alternate sets overlap in such a manner as to form one instead of two rows on each side, the type is known as four-rowed barley (*H. sat. vulgare* Hackel), frequently called bere or bigg in England. In the six-rowed type it not infrequently happens that it is only four-rowed towards the tip of the spike.




**Six-rowed barley:** on the left three single grained spikelets at one joint of the rachis, each with two outer glumes, *c*. In the spike on the right there are in view only two rows made up of the outer grains, *a*, of the spikelets upon opposite sides of the rachis. Spikelet, natural size; spike, one-third natural size.




Two-rowed barley: on the left, three spikelets at one joint of the rachis, the outer two, *a*, being rudimentary, the middle one, *b*, only having developed into a grain; *c*, outer glume. The rudimentary, *a*, and developed, *b*, grain are shown in spike on the right. Spikelet, natural size; spike, one-third natural size.

In the two-rowed type the lateral grains have failed to develop through the abortion of the ovulary, although the stamens may be present. The flowering glume and palea remain in a somewhat rudimentary form, while the outer glumes are fully developed. In the six-rowed type the joints of the rachis are closer together and less in number, making a shorter and much more compact spike than in the two-rowed, but with grains somewhat more numerous. In the two-rowed type the spike is distinctly compressed laterally, while in the six-rowed an end view is somewhat star-shaped. The two-rowed varieties have the greater tendency to tiller.[1] There is a hull-less barley (*H. nudum* L.), also known as naked or bald barley. This type is beardless, and is divided into white, purple and black varieties. There are also beardless varieties among the types which retain the hulls.


Beardless barley. One-third natural size.

It is probable that all these different types are due to cultivation. Which is the original type appears less clear. Hackel believes that cultivated barley originated from *H. spontaneum* C. Koch, which resembles closely the two-rowed type.[2] On the other hand, it appears that the type most universally cultivated from earliest times has been the six-rowed type; the widespread cultivation of the two-rowed type in Europe being comparatively recent, although of its ancient culture there is no doubt.[3]

448. **Two and Six-Rowed Varieties.**—At the present time, two-rowed barley is almost universally raised in Europe for the production of malt. When the four or six-rowed barley is raised there it is generally used as food for domestic animals. The two-rowed varieties appear to be preferred by European malters because of their thin hull and low per cent of protein,

[1] Soc. Prom. Agr. Sci., 1899, p. 80.

[2] True Grasses, p. 189.

[3] De Candolle: Origin of Cultivated Plants, p. 367.

both contributing to a higher per cent of malt extract. In America, the six-rowed barley is grown chiefly, although not exclusively, and is freely used in the production of malt. (445)

In a comparative test of two-rowed and six-rowed varieties at the Central Experimental Farms of Canada, the former were from five to twelve days later in maturing. At the five experimental farms of the Dominion the average yield during several years was about the same for both types. At the Central Station at Ottawa, where the conditions correspond to those of Ontario and Quebec, the six-rowed varieties yielded about one-fifth more grain.[1] Similar results have been obtained on the Ontario Agricultural College Farm at Guelph.[2] While giving fair returns, the Wisconsin Station found the two-rowed varieties to have frail straw, and, therefore, to lodge badly.[3]

449. **Winter and Spring Varieties.**—The two-rowed barley is a spring variety. The six-rowed is both fall and spring sown. Fifty years ago barley was commonly fall sown in Missouri, Kentucky and southern Ohio, but the practice of fall sowing has largely disappeared and spring sowing, usually further north, has taken its place. It is claimed, and it seems probable, that in some instances winter strains were converted into spring strains by spring sowing. Soule states that the Tennessee Station has obtained as good results with fall sown barley as Northern States usually obtain with spring sown. Maryland Station obtained a yield of forty-eight bushels with winter barley and twenty-six bushels with spring barley.[4] Very little barley, however, of any sort is raised in the Southern States, and then chiefly for pasturage.

450. **Varieties.**—There are three types of barley grown in North America known to the trade as quite distinct: viz., Scotch,

[1] Can. Expt. Farms Bul. 21, p. 40.

[2] Ont. Agr. Col. and Expt. Farms Rpt. 1900.

[3] Wis. Rpt. 1903, p. 265.

[4] Md. Bul. 35, p. 191.

Bay Brewing and Chevalier. (473) The use of these terms in trade does not correspond closely to variety types.

Scotch is a six-rowed barley said to have been introduced into Wisconsin from Canada in 1866 by William Buchheit, Waterton, Wis. It has since been largely raised in Wisconsin, Iowa and Minnesota. Bay Brewing or California Bay is a six-rowed variety originally raised in a small district lying south of the Bay of San Francisco, but now more widely distributed in California. Chevalier is a well-known European two-rowed variety said to have been originated in 1819 through selection by the Rev. J. Chevalier, rector of Stoneham, Suffolk, England. Manshury is a standard variety that has been tested and distributed by the Wisconsin Station.

"This variety originated in Manchuria, China. A scientific traveler in 1859 brought some from Eastern Asia to Germany, and it was grown in the King's garden at Sans Souci with success. Dr. Herman Grunow, Mifflin, Iowa county, Wis., while on a visit to Germany was advised to try some in America, and brought home with him two pounds of the seed. This was sown and compared with about a dozen other varieties and proved much superior to any on trial."[1]

Oderbrucker, a six-rowed variety imported from Germany by the Ontario Agricultural College, resembles Manshury closely. Among fourteen stations in the United States and Canada which have tested varieties of barley for periods from one to ten years, twelve included Manshury (six-rowed) and eight Chevalier (two-rowed) among their recommended list of varieties. No other variety is recommended by four stations.

The yield of grain of hull-less varieties is usually less than varieties bearing hulls, due in part to the absence of the hulls. The straw is weaker and more liable to lodge, thus further reducing the yield harvested. The Ontario Agricultural College, as the result of testing eight varieties of hull-less barley for ten years, recommends Guy Mayle, Black Hull-less and Purple.[2] The Arizona Station recommends beardless varieties for hay,

[1] Wis. Rpt. 1903, p. 265.

[2] Ont. Agr. Col. and Expt. Farms Rpt. 1903, p. 133.

because the bearded varieties are irritating to the mouths of horses and often injurious.[1]

451. **Breeding Barley.**—Saunders crossed a six-rowed variety known as Baxter upon a Swedish two-rowed variety Royal, a six-rowed variety, and Beaver, a two-rowed variety, have been obtained, each of which has stiff straw, is a vigorous grower and productive.[2] Johannsen, by systematic selection of heads with heavy grains and low nitrogen content for three generations, has obtained a progeny of the fourth generation with somewhat higher average weight of grains and appreciably lower nitrogen content.[3] Remy has selected strains of drouth resisting barley, such plants being shorter in the straw and shorter and closer in the head than those requiring a greater quantity of water.[4]

## III. CLIMATE AND SOIL

452. **Climate.**—Barley is successfully cultivated in a wider range of climate than any other cereal. It is cultivated from 65° N. Lat. in Alaska to semi-tropical California. (391) It is said to mature in the Andes at an elevation of 11,000 feet. While growing freely in Chile at 5,000 feet, it rarely ripens on the plateaus of Peru, which have an elevation of 9,000 feet.[5] Grain is produced in Colorado at 7,000 feet and heavy crops of hay at 8,500 feet. In California, where, for climatic reasons, neither oats nor maize is grown extensively, barley is an important crop, both for grain and hay

Brewer has shown that in 1880 the greatest production of barley in the United States was with a smaller annual rainfall

1 Ariz. Rpt. 1899, p. 249.

2 Soc. Prom. Agr. Sci. 1899, p. 80.

3 Medd. Carlsberg Lab. 1899, No. 4, pp. 228-313. E. S. R. XII, p. 326.

4 Deut. Landw. Presse, 29 (1902), Nos. 87, p. 706, Fig. 1; 88, pp. 715, 716. E. S. R. XIV, p. 650.

5 Int. Encycl., Vol. II, p. 487.

and a smaller amount during the growing season than any other cereal. Although an important crop in Norway and Sweden, it was formerly the bread plant of the people bordering on the Mediterranean Sea. It is said to grow in the extreme North, where the soil melts only a few inches deep. It seems, however, to be best adapted to a warm, dry climate, although an abundance of rain does not prevent its successful culture. It requires less water in the Western States for irrigation than wheat or oats, and can be successfully grown more seasons in the semiarid region without irrigation than oats or spring wheat.

The average maturing period is less than for oats or spring wheat. At the Wisconsin Station during five years it has varied with different varieties from seventy-eight to eighty-eight days, the average being eighty-four days; at North Dakota Station the season has varied from eighty-two to ninety-four days. (386)

453. **Soil.**—Whether the peculiar distribution of barley in the United States is in any way dependent upon soil has not been ascertained. The development and distribution of the culture of a crop are due to so many causes, natural and economic, as to make it difficult to trace soil influences. The indications are, however, that the nature of the soil makes more difference with barley than with other cereal crops. English experience would indicate that rather sandy and well drained soils are better than clay soils or soils not well drained. Barley needs a fertile soil, and does not appear to stand growing continuously on the same land as well as other cereals. The rate of decline of barley at Rothamsted during forty years of continuous culture without fertilizers was considerably greater than in the case of wheat.

454. **Rotation.**—Perhaps no cereal crop requires more care bestowed upon the rotation than does barley. Where barley replaces the wheat crop, the rotation may be maize, barley and

oats, each one year; or timothy and clover one or more years. The land has thus had surface tillage the previous year and may have been manured. In some regions barley replaces oats, when the rotation becomes maize, barley and wheat, each one year, followed with clover or clover and timothy one or two years. It is a matter of observation that the yield of winter wheat following barley is better than that following oats, especially in regions where water is readily exhausted from the soil. This is doubtless due to the greater water requirement of oats as compared with barley, which makes it more difficult to prepare a suitable seed bed, and causes the wheat subsequently sown to germinate and grow more slowly.

It is thought that the extensive experiments of Lawes and Gilbert indicate that the quality of barley is injured by following root crops, and is best in England when following wheat. All the various cultural conditions combined, however, have less influence on both quantity and quality of produce than has the weather.[1]

455. **Manuring.**—As the straw is comparatively short, barley will stand liberal manuring without lodging. Where lodging occurs, the filling of the grains is less interrupted than in the case of oats. Stable manure or commercial fertilizers may be applied directly to land intended for barley in quantities suggested for wheat. (122, 123, 124) Generally, however, it is better farm practice to apply the manure to the previous maize crop, and, if further fertilizing is required, apply commercial fertilizers for the barley. That barley responds as well as other cereal crops to the use of various forms of fertilizers is shown by the following table, giving the average yields of barley, wheat and oats during sixteen years on the same land at the Central Experimental Farms, fertilizers having been applied continuously during the first eleven years:[2]

1 Jour. Roy. Agr. Soc. England, 3 Ser. 11 (1900), pt. 2, pp. 185–251, pls. 11.

2 Can. Expt. Farms Rpt. 1903, p. 24 *et seq.*

**Yield of Grain per Acre in Bushels—Average Sixteen Years.**

| | Barley | Spring wheat | Oats |
|---|---|---|---|
| Unmanured | 14 | 11 | 29 |
| Barnyard manure | 35 | 23 | 53 |
| Nitrogen | 21 | 14 | 46 |
| Phosphorus[1] | 18 | 13 | 36 |
| Potassium | 23 | 16 | 39 |
| Nitrogen and phosphorus | 25 | 13 | 48 |
| Phosphorus and potassium | 23 | 14 | 42 |
| Nitrogen, phosphorus and potassium | 27 | 14 | 44 |
| Salt | 27 | 14 | 38 |
| Gypsum | 20 | 13 | 35 |

Salt and gypsum both appear to have increased the yield of barley, but to have had less influence on the oats and wheat. Barley appears more dependent on the manurial supplies within the surface soil, probably on account of its shorter period of growth and more limited range of roots. For the same reason, soluble fertilizers, where needed, appear the most effective.

1 Phosphorus applied in untreated phosphates.

# XXII.

## BARLEY.

### I. CULTURAL METHODS.

456. **Preparation of Seed Bed.**—A well prepared seed bed is desirable if not essential for barley. To this end the land should be plowed and the seed bed deeply and thoroughly pulverized. Fall plowing is preferable in order to secure early preparation of seed bed and early seeding. The same principles apply to depth of seeding as in wheat, oats and maize. The Minnesota Station obtained higher yields from sowing three-fourths inch deep than from deeper seeding, and one and one-half inches than either deeper or shallower seeding in another instance.[1] At the Manitoba Station better results were obtained at two inches than at shallower or deeper seeding.[2] Much barley is sown broadcast, although the Ontario Agricultural College has found best results from drilling.[3] For malting purposes it is desirable that every plant be grown and matured under as uniform conditions as possible. Doubtless drilling will promote this end. In some instances increased yields of grain have been obtained by mixing barley with other grains, such as oats. (404) In no case should two and six-rowed varieties of barley be mixed if their crop is to be used for malting, because of different lengths of time required for germination. Barley may be mixed with field peas in place of oats for sowing after July first, because the former is better adapted to growing during the warm weather. Early seeding of barley with field peas is less

[1] Minn. Buls. 31 and 40.

[2] Can. Expt. Farms Rpt. 1900.

[3] Ont. Agr. Col. and Expt. Farms Rpt. 1898.

desirable than oats with field peas on account of the weakness of the straw.

457. **Rate of Seeding.**—Wide variations in rate of seeding, ranging from one and one-half to four bushels of seed per acre, have given the best results in different trials. Two bushels is the usual quantity of seed sown per acre. It seems probable, however, that seeding at the rate of ten pecks per acre will give the best average results. The number of seeds per bushel is usually rather less than in wheat and oats. Barley tillers less strongly than oats, and also less strongly at least than *winter* wheat. Seeding thinly enough to induce excessive tillering may cause irregular and later ripening.

458. **Time of Sowing.**—The Central Experimental Farm, at which the conditions correspond to those of Ontario and Quebec, sowed two varieties of barley at six weekly periods for ten years, beginning each year as early as the land was fit to receive the seed. Seeding either the first or second week gave the best results. The decrease in yield after the second week was marked. In these provinces seeding usually should be finished before May first. The Ontario Agricultural College obtained best results every year during four years between April 22 and 25. Early sowing was not found so important for the Maritime Provinces, Manitoba, the Northwest Territories or British Columbia. The seeding should be finished in these provinces generally between May 15 and 25.[1]

The barley plant when young is rather more susceptible to cold than wheat and possibly than oats. A light frost just after it is up is likely to injure it. In the spring wheat regions barley is generally sown after wheat is sown, and before oats are sown, although in some sections barley is sown after oats. It is probable that oats would suffer more than barley from a few days' delay in seeding. At the Minnesota Station the difference in

[1] Can. Cent. Expt. Farms Bul. 21; Can. Expt. Farms Rpt. 1899; Ont. Agr. Col. and Expt. Farms Rpt. 1898.

favor of early seeding of barley was much less than with spring wheat, oats and flax.[1] The Tennessee Station found September decidedly the best month for the fall seeding of barley.[2]

459. **Seed Selection.**—The Ontario Agricultural College has obtained an average for six years of fifty-four bushels from sowing large plump seed; fifty bushels from small plump seed; forty-six bushels from shrunken seed, and forty-three bushels per acre from sowing broken grains produced by the usual process of threshing.[3] The Tennessee Station sowed large seed that were twenty-eight per cent heavier than small seed, and obtained fifty bushels from the larger seed and forty bushels per acre from the small seed. The weight of the individual grains was, however, practically identical in both cases. Large grains from large heads gave a larger yield of grain than from medium or small heads.[4]

460. **Harvesting.** — Barley that has been allowed to ripen fully will be likely to have the most mealy endosperm, and most likely to sprout uniformly. On the other hand, if allowed to ripen fully, there is more danger of discoloration from rain and dews, and as this character is counted so important in fixing the commercial grade, early cutting is frequently practiced.

If bundles are shocked promptly and shocks are carefully capped with two bundles, ripening may proceed, and both ends —full maturation and bright color—be measurably secured. (160) Formerly the barley crop was usually cut with a self-rake reaper and laid off in small gavels or in continuous swaths. These were allowed to dry a day or so, as required, and then raked together, or, more usually, placed in piles by hand with a large wooden, four-tined fork. The aim was to get the barley

1 Minn. Bul. 40, p. 282.

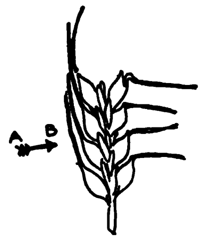
2 Tenn. Bul. Vol. XIV, No. 3, p. 6.

3 Ont. Agr. Col. and Expt. Farms Rpt. 1903, p. 119.

4 Tenn. Bul. Vol. XIV, No. 3.

dry as quickly as possible, so that it might be subject as little as possible to the rains and dews before reaching the stack. The severity of the beards and the shortness of the culms made it almost impossible to bind by hand. With the self-binder, it is the easiest of our cereal crops to bind. The shocking is now the most unpleasant operation. Barley of as good color is not obtained ordinarily when the sheaves are bound as when they are left open, chiefly because it is necessary to allow it to be long exposed to the weather before stacking or threshing. Considerable improvement in color may be effected by threshing the cap sheaves separately, and using the grain from them for food for domestic animals.

461. **Threshing.**—Pieces of broken grains containing no embryos are valueless for the production of malt, since their contents do not become soluble. Moreover, they are harmful, since such grains become covered with mould, serving as a center of infection to the sprouting grains, and thus injuring the malt. Grains that have the ends of the hulls broken off too closely; a portion of the hull peeled off; or grains that are merely bruised, although germinating, are also liable to be attacked with mould. Special care should be taken, therefore, in threshing barley, not to break or bruise the grains. It is better to leave a little of the beard on than to injure the grains. This will reduce the weight per bushel, but maltsters are coming to recognize that high weight per bushel is less important than injured grains, and that no harm results from leaving on a little of the beard. Care should be taken to regulate the number and closeness of the concaves of the threshing machine and not to run the cylinder at too high a rate of speed. Since



Portion of spike of barley, showing the influence of threshing upon perfect grains. Assuming the cylinder to strike the spike in the direction AB, beards on left will be broken off properly, while those on the right may carry a part of the husk or flowering glume with them. (After Baird.)

the beard is on the flowering glume, or that portion of the hull farthest from the center of the spike, any pressure from without will break the beard off without disturbing the hull, while pressure from within outward is liable to peel off a portion of the hull. Obviously the extent of such injury will depend upon the condition of the grain at the time of threshing.

## II. FUNGOUS DISEASES AND INSECT ENEMIES.

462. Fungous Diseases.—Barley is subject to black stem rust and orange leaf rust, as in wheat. (146) The leaves are also attacked by the conidial stage (*Oidium monilioides* Lv.) of the powdery mildew (*Erysiphe graminis* D. C.), whose greyish, mouldy tufts cause discoloration of the tissue. The loose or naked smut (*Ustilago nuda* (Jens.) Kell. and Sw.) not infrequently reduces the spikelets to a sooty mass of spores. The covered smut (*U. hordei* (Pers.) Kell. and Sw.) is less common. The modified hot water treatment may be used for both smuts. Soak the seed grain for four hours in cold water, let stand four hours in wet sacks, then immerse for five minutes in water at a temperature of 130° F., which is three degrees lower than for wheat. (148) It has been shown that formalin solution will kill covered smut.[1]


Loose smut on barley: A, two-rowed variety; B, six-rowed variety. One-third natural size.

463. Insect Enemies.—Barley is comparatively free from insect attacks. However, barley probably suffers more from attacks of chinch bugs than any other cereal; whether it is because the chinch bugs prefer the barley or the barley is less able to resist their attacks is less clear. (151) The Hessian fly also attacks barley, although ordinarily it is not so destructive as in wheat (152); so also does the wheat bulb worm. (153) Barley is also attacked by a joint worm (*Isosoma hordei* Harris), which produces galls at or near the nodes or joints of the culm.

1 E. S. R. XII, p. 457.

III. USE.

464. **Use.**—Barley is chiefly used as a food for domestic animals and for malting purposes. Barley meal is a suitable food for all classes of domestic animals wherever maize would be found desirable, which it nearly equals in feeding value. In Europe it takes the place largely which maize does in America. In this country, its use as a stock food is not general as compared with maize or oats, except in the Pacific Coast States, where it is largely raised, not only for its grain but also for hay. Barley is little used in this country as an article of human food, principally as pearl barley. Pearl barley is the naked kernel, the hull having been removed by special machinery. Barley straw is at least equal in feeding value to oat straw. When used as bedding, one part of wheat straw has been found to absorb 2.2 parts of water, oat straw 2.28 parts, while one part of barley straw has been found to absorb 2.85 parts of water.[1]

465. **Use for Malting.**—While oats and wheat are sometimes used in the production of malt, barley is preferred because it develops less insoluble proteids, has greater peptonizing and diastatic power. It is also preferred to wheat on account of its hull. (440) Maize is not desirable on account of its high per cent of fat. While neither maize nor rice is used for malting, both are largely used in the manufacture of beer as raw cereals, the rice having its hull removed and the maize being degerminated. Both are used with malt.

466. **By-Products.**—There are two by-products in the production of malt extract: (1) malt sprouts and (2) brewers' grains. Both are placed upon the market in the wet and dry state. For sanitary reasons, they are best purchased in the latter state. Malt sprouts, as the name implies, are the sprouts or young barley plants which have been sprouted for the purpose of changing the starch of the barley into a soluble form where it

1 E. S. R. V, p. 144.

can be extracted with water. These young plants, like all young plants, are rich in protein and as usually sold form a cheap and satisfactory source of protein for milch cows. The brewers' grains consist of that portion of the barley which is left after the removal of the sprouts and extraction of the carbohydrates made soluble through sprouting. They also form an acceptable food for milch cows, although they are less nitrogenous than malt sprouts. They may also be fed to fattening cattle and to horses. Neither is desirable for swine on account of the crude fiber contained. The composition of the dried forms is as follows:[1]

| | Malt sprouts | Brewers' grains |
|---|---|---|
| Water | 11.0 | 8.0 |
| Ash | 5.8 | 3.8 |
| Protein (N x 6.25) | 27.1 | 23.1 |
| Crude fiber | 11.9 | 10.8 |
| Nitrogen-free extract | 42.6 | 49.4 |
| Fat | 1.6 | 4.9 |

From one-fourth to two-thirds of the protein of the malt sprouts may be in the form of amides. The nitrogen-free extract of the brewers' grains consists largely of pentosans and not true starch. Barley feed, a by-product in the manufacture of pearl barley, is produced in small quantities. It makes a rather low grade feed. Barley screenings, when ground, form an acceptable carbonaceous food.

## IV. PRODUCTION AND MARKETING.

467. **Barley Crop of the World.**—The world's production of barley varied during the five years 1898 to 1902 from 921 million (1900) to 1,177 million (1902), with an average annual production of 1,013 million bushels. The following table shows the average annual production of barley for five years by continents in million bushels:

[1] Mass. (Hatch) Bul. 94.

| | 1898–1902 |
|---|---|
| Europe | 788 |
| North America | 124 |
| Asia | 50 |
| Africa | 48 |
| Australasia | 3 |
| Grand total | 1,013 |

Russia, Germany and Austria-Hungary, in order named, are the principal barley producing countries, contributing two-thirds the combined production of Europe and Asia.

468. **Barley Crop of the United States.**—In extent of production, barley ranks fourth among the cereals in the United States. The crop is, however, of much less importance than wheat, maize or oats. The acreage of wheat is more than one-half, that of oats less than one-third, and that of barley about one-twenty-fifth the acreage of maize. Relatively, the acreage of barley is increasing. In common with the other cereals, barley has decreased in value per bushel; the average price during the ninety decade was forty-three cents, a decrease of sixteen cents from the previous decade. The value per acre in 1899 of the four crops named above was: wheat, $6.90; oats, $7.24; maize, $8.71; barley, $9.34.

469. **Barley Crop of Canada.**—The following table shows the average annual production of five cereals in the United States and Canada for five years, 1898-1902 inclusive, in million bushels: [1]

| | Canada | United States | Ratio 1: |
|---|---|---|---|
| Barley | 27 | 87 | 3.5 |
| Wheat | 74 | 633 | 8.5 |
| Oats | 132 | 812 | 6.1 |
| Maize | 25 | 2,031 | 81.2 |
| Rye | 4 | 28 | 7.0 |

[1] U. S. Dept. of Agr. Yearbook 1902, 1903.

**470. Center of Barley Production.**—In 1850 the North Atlantic division produced eighty-one per cent of the barley crop of the country; in 1900 the North Central division produced sixty-eight per cent, and the Western division twenty-eight per cent. The center of production has moved westward from about the center of New York in 1850 to near the junction of Iowa and South Dakota in 1900. In 1850 New York reported 69.4 per cent of the entire barley crop; in 1900, while reporting nearly the same number of bushels as in 1850, her contribution was only 2.5 per cent of the entire crop. The growth of barley is so concentrated in this country that nine States furnish ninety-one per cent of the total production. To produce an equal percentage of the maize crop, nineteen States would be required. The nine States referred to are California, Minnesota, Wisconsin, Iowa, South Dakota, North Dakota, Washington, New York and Nebraska; the first four of which produce three-fourths of the total crop.

**471. Yield per Acre.**—The average annual yield per acre of barley during the decade 1893-1902 was nearly twenty-four (23.7) bushels, an increase of more than one bushel over the previous decade. The yield per acre is quite uniform in all except the Southern States, which yielded about four bushels below the average. Thirty-five to forty bushels is considered a good yield per acre, and where the soil and weather conditions are very favorable, a higher yield may be obtained.

**472. Exports and Imports.** — During the past decade the annual export of barley has been about eleven per cent of the production, San Francisco being the chief exporting center. The United Kingdom, Australasia and Portuguese Africa receive the largest quantities of the exported grain. The import has been comparatively small, coming chiefly from Canada.

**473. Commercial Grades.** — The Illinois Board of Railroad and Warehouse Commissioners recognizes the following classes and grades:

Barley Nos. 1, 2, 3, 4 and 5.
Scotch barley Nos. 1, 2 and 3.
Bay Brewing barley Nos. 1, 2 and 3.
Chevalier barley Nos. 1, 2 and 3.

The rules for grading barley are as follows:

"No. 1 Barley.—Shall be sound, plump, bright, clean and free from other grain.

"No. 2 Barley.—Shall be of healthy color, not sound enough and plump enough for No. 1, reasonably clean and reasonably free from other grain.

"No. 3 Barley.—Shall include all barley slightly shrunken and otherwise slightly damaged barley, not good enough for No. 2.

"No. 4 Barley.—Shall include all barley fit for malting purposes, not good enough for No. 3.

"No. 5 Barley.—Shall include all barley which is badly damaged, or from any cause unfit for malting purposes, except that barley which has been chemically treated shall not be graded at all."

Grades for Scotch, Bay Brewing and Chevalier barley are the same as for barley, except they must be of the variety named, and in the case of the last two shall be grown in the Western States. More No. 3 barley is dealt in on the Chicago market than any other class or grade. The most important item in fixing the grade is the color, which should be as light as possible. Rains or dews readily discolor the hull after the grain is ripe and greatly lower the grade. No. 2 barley must weigh forty-eight pounds to the bushel, while No. 3 barley may weigh a "few" pounds less.

## V. HISTORY.

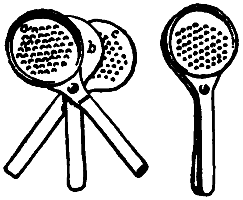
474. **History.**—The culture of barley is very ancient. Both it and wheat were cultivated before we have any history of man. In ancient Egypt it was used as food for man and beast, and also made into beer. It was the chief bread plant of all those nations from which we derive our civilization. Barley continued to be the chief bread plant of continental Europe down to the sixteenth century. The introduction and wide cultivation of potatoes and the rapid development of the growth of wheat have brought about a decline in the use of barley. Barley was used

to some extent by both man and beast in the early colonies of this country.

## Practicums.

475. THE PLANT.—Each student should be given a printed or typewritten sheet, as indicated below, and requested to describe two or more types or varieties, as indicated. The study may be made in the field, or from fresh or dried specimens in the laboratory.

1. Height of culm: average of ten culms to tip of upper beard . . .
2. Vigor of plant: strong; medium; weak.
3. Diameter below spike: average of ten culms . . .
4. Wall of culm: thick; medium; thin.
5. Color of culm: light yellow; yellow; bronze.
6. Foliage: scanty; medium; abundant.
7. Rust: leaves, per cent . . .; culms, per cent . . .
8. Smut: per cent . . .
9. Spike: erect; leaning; nodding.
10. Spike: two-rowed; four-rowed; six-rowed.
11. Length: average of ten spikes from lower joint of rachis to tip of flowering glume (not counting beard) of upper spikelet . . .
12. Number of joints of the rachis: average ten . . .
13. Number of spikelets at joint of rachis . . .
14. Number of grains per spike: average ten spikes . . .
15. Weight of middle and lateral grains (if six-rowed): average ten grains: middle . . .; lateral . . .

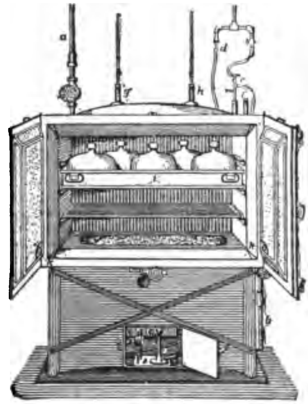



Grobecker's grain tester. Move handle of knife, *b*, to the right, thus opening the receiver, *c-a*; put the barley to be tested into cup, *a*, when, by slightly shaking the instrument, the grains will fill the fifty holes. Now press the knife, *b*, back to its original position, thereby cutting each grain crosswise through the middle. Then move handles, *a* and *b*, aside, thereby laying open part *c*, when the number of mealy, half mealy and glassy grains may be counted.

476. THE GRAIN.—Furnish each student with one quart of the grain of two or more varieties of barley, preferably a two-rowed, six-rowed and hull-less variety.

1. Color of grains: light yellow; yellow; dark yellow.
2. Impurities: remove perfect and broken grains from ten grams; weight of perfect grains . . .; weight of broken grains . . .
3. Volume weight: weight per bushel obtained by weighing one pint . . .
4. Specific gravity: use picnometer (203) . . .
5. Weight: one hundred grains . . .
6. Hull: thick; medium; thin; per cent in twenty-five grains . . .

7. Character of endosperm: mealy . . . per cent; half mealy . . . per cent; glassy . . . per cent.
8. Character of endosperm: opaque . . . per cent; half opaque . . . per cent; translucent . . . per cent.
9. Plumpness: plump; medium; shrunken.
10. Length of grain: ten grains . . .
11. Width of grain: ten grains . . .
12. Thickness of grain: ten grains . . .
13. Germination: place 100 grains between well moistened filter paper or flannel cloth, and keep at temperature of 80° F. Remove sprouted grains at end of each twenty-four hours for five days; first day . . .; second . . .; third . . .; fourth . . .; fifth . . .



Seed germinating apparatus used by the United States Department of Agriculture. *a*, inlet pipe; *b*, outlet pipe; *c*, thermo-regulator; *d*, "guide light" gas delivery tube; *e*, "guide light"; *f*, opening into water cavity; *g*, maximum and minimum thermometer; *h*, thermometer; *i*, germinating pan; *kk*. outlets for carbon dioxide. (Yearbook 1894, p. 402.)

477. Soil Fertility in Relation to Barley.—Barley is well adapted for pot culture. (432) Where practicable, require each student to apply the following fertilizing ingredients in the rates per acre indicated below. Require the student to calculate the amount of fertilizers required per plat from such commercial goods as may be available in his market. Also require the student to show the method of calculating yields from check plats. See Ohio Bul. 138, p. 40. Make each plat four to eight rods long and the width of one round of the wheat drill. Leave three feet between each plat, and keep this space cultivated so as to prevent growth of weeds. Outer drill row may be cut by hand and discarded in order to get yields similar to those obtained in ordinary practice. Where practicable, each student should be required to carry this trial through from start to finish, calculating fertilizers required, mixing materials from raw goods, applying fertilizers, sowing barley (wheat or oats may be substituted), harvesting crops and calculating yields. Reasons for each of the steps taken should be emphasized.

Place upon the plats commercial fertilizers in quantities equivalent to pounds of elements indicated:

1. None.
2. Phosphorus, 25.
3. Potassium, 25.
4. None.
5. Nitrogen, 25.
6. Phosphorus, 25; nitrogen, 25.

7. None.
8. Phosphorus, 25; potassium, 25.
9. Potassium, 25; nitrogen, 25.
10. None.
11. Phosphorus, 25; nitrogen, 25; potassium, 25.
12. Phosphorus, 50; nitrogen, 25; potassium, 25.
13. None.
14. Phosphorus, 25; nitrogen, 12.5; potassium, 25.
15. Stable manure, 10 loads.
16. None.
17. Stable manure, 10 loads; lime, 1,000 lb.
18. Stable manure. 20 loads.
19. None.

478. Collateral Reading.

Cultivated Barleys. By John Percival. Agricultural Botany, pp. 481-492. London: Duckworth & Co. (1900).

Results of Experiments at Rothamsted on the Growth of Barley for more than thirty years on the same land. By J. H. Gilbert. Rothamsted Memoirs, Vol. VI, pp. 1-29. London: Dunn & Chidgey (1890).

Barley. By Wahl-Henius. American Handy Book of the Brewing, Malting and Auxiliary Trades, pp. 449-463. Chicago: Wahl and Henius (1902).

# XXIII.

## RYE.

479. **Relationships.**—The commonly cultivated species of rye (*Secale cereale* L.) has its outer glumes shorter than the flowering glume; while in another species (*S. fragile* Biberst) to be found in Hungary and southern Russia, there is a long awn on the outer glume extending beyond the flowering glume. Both species are annual. According to Hackel, the original species (*S. montanum* Guss) extends from Spain and Morocco to central Asia. It is perennial and the rachis breaks apart upon ripening, both of which characters are lost under cultivation. It is said that rye stubble allowed to stand a long time in the field will sprout again; while this never happens with wheat and barley because the original forms are annual. Rye is more closely related to wheat than to any other cereal, although differing from it in several particulars.

480. **The Plant.**—When a grain of rye germinates it throws out a whorl of four instead of three temporary roots; a fact which may in some way account for its greater hardiness. Its culms are longer, more slender, and tougher than those of wheat. The rye spikelet is only two-flowered and both flowers develop about equally, making the spike rather uniformly four-rowed. The outer glumes are awl-shaped instead of boat-shaped, as in the case of wheat. The flowering glume is always awned and the keel of the glume is strongly barbed. A rye spike is rather longer than a wheat spike, being usually four to six inches long, not counting the beards. The joints of the rachis are rather farther apart, there being twenty to thirty in a single spike. Unlike wheat, the lower spikelets are fertile and produce

normally sized grains. The organs of reproduction are very similar to those of wheat, except that the anthers in the case of rye are very much larger. A rye grain is rather longer, more slender, more pointed at the embryo end and more blunt at the upper end. One hundred average grains weigh about 2.5 grams, usually varying between 2.25 and 3.75 grams. In some cases the size of seed may vary so that one and one-half to three and a quarter bushels might furnish the same number of seed per acre. The furrow or crease is less marked and the surface is more wrinkled. This may be due to the more porous cells of the pericarp. Its general resemblance to an oat kernel has caused rye to be used in adulterating oats when the former is cheaper than the latter per pound. In general the structure of the rye grain is similar to that of the wheat grain, although the starch cells and cells of the aleurone layer appear rather larger in the case of rye.

Rye at blooming: front view of spike on right; side view of portion of spike in middle; on the left, a single spikelet containing two flowers about to bloom; shows outer glume, flowering glume, large anther and palea.

481. **Composition.**—Analyses of American rye indicate that the percentage of protein (10.6) and fat (1.7) is somewhat less than that of wheat. The protein contains gluten, and rye flour is therefore adapted for the production of porous bread. The

grain of rye is less variable in composition than wheat, barley or maize. Analyses of American rye flour show the percentage of protein to be very much less than that of wheat flour, being, on an average of four analyses, 6.7 per cent in the case of rye flour, and 10.8 per cent as an average of twenty analyses of wheat flour. The difference in the composition of rye and wheat straw is very slight. It is probable, however, that there is considerable difference in the nitrogen-free extract, since rye straw is much tougher, and recognized to be of little value for feeding purposes.

482. **Varieties.**—There are very few varieties of rye, probably because rye cross-fertilizes freely. There are both spring and winter varieties, the latter being usually sown. In America, at least, practically no attempt has been made to improve rye either by selection or crossing.

483. **Climate.** — Rye is a hardy plant and stands severe winters better than wheat. It has been matured in Alaska as a winter grain.[1] It does not seem, however, especially influenced by hot weather. It is, nevertheless, naturally a plant of cold climate just as barley is one of warm climate.

484. **Soil.**—Rye is adapted to light, sandy soil. It has been called the grain of poverty, because it will produce a fair crop on land too poor, or climate unadapted for other cereals.[2] It will thrive on much poorer soils than wheat, maize or barley. This is so well recognized that the expression, "It is too poor to grow rye," is used to indicate the extreme poverty of the soil. Brewer states that the feeling that poor soil and the growth of rye are connected prevents many farmers from raising it for purely sentimental reasons. While fertilization of rye, therefore, is not systematically practiced, the same principles apply to rye as to wheat. (122, 123, 124)

1 Office of Expt. Sta. Rpt. 1903.

2 Sargent: Corn Plants, p. 83.

485. **Rotation.**—Ordinarily rye occupies the place in the rotation assigned to wheat. It is an excellent crop with which to seed down land to grass and clover, and in sections on the northern border of the winter wheat district, rye, on account of its greater hardiness, is sown in place of wheat for this purpose. The Rhode Island Station has obtained satisfactory results with a six-course rotation as follows: first year, winter rye; second year, timothy, redtop and medium red clover; third year, grass; fourth year, grass; fifth year, maize; and sixth year, potatoes. No stable manure was used, but liberal quantities of commercial fertilizers were applied to all crops. In undertaking to build up "worn-out" land with this rotation, it is considered desirable to begin with rye.[1] It has been reported that in Europe rye frequently gives unsatisfactory results when grown after potatoes.[2]

486. **Rye as Green Manure.**—On account of its hardiness and its ability to grow upon poor soil, rye makes a good crop to grow for plowing under to increase the organic matter in the soil. Rye may be sown in the standing maize in September (128), or, after maize is shocked, may be disked in without plowing. In the spring, rye may be plowed under and land planted again to maize or sown to some other crop. Care should be taken, however, to plow the rye under early in the spring before it has made too much growth, lest it exhaust the moisture from the soil and thereby reduce the subsequent crop. It has been shown that by allowing the rye to head out and removing the crop, the subsequent maize crop may be seriously injured.[3] In sowing rye in standing maize, no advantage is gained by sowing before September, since the maize plant so shades the ground as to retard the growth of the earlier sown rye. Sowing rye between two potato crops did not reduce the

1 R. I. Bul. 99.

2 Fuhling's Landw. Ztg. 47 (1898), No. 18, pp. 702-706; E. S. R. X, 740.

3 Ohio Agr. Rpt. 1895, p. 311.

scab, and decreased the yield of potatoes.[1] As a cover crop for orchards, either alone or with hairy vetch (*Vicia villosa* Roth), rye has given satisfactory results.

487. **Cultural Methods.**—The same principles apply to the preparation of the seed bed and the methods of seeding as in the case of winter wheat. Ordinarily where both wheat and rye are sown, the rye is sown first. No experiments have been reported with regard to the best quantity of seed per acre applicable to American conditions. In an experiment in Denmark, seeding in varying rates from two to three and one-fourth bushels per acre, the largest yield of both grain and straw was obtained by sowing at the rate of two and one-half bushels, or 2,280 million grains, per acre during an average of three years. The percentage of grain per straw and the size of grains were larger at the thinner seeding. From one and one-half to two bushels of rye per acre is usually sown in this country. Where grown for soiling the seeding may be heavier. In a ten years' trial with different sized seed only a slight increase in grain and straw was obtained from the larger seed; the increase being rather greater in the straw than in the grain.[2]

Rye is not infrequently pastured in the fall with either cattle or sheep, and sometimes again in the spring, after which the stock is removed and the rye allowed to ripen. While this reduces the yield, rye will stand this treatment better than any other cereal crop. In case rye makes too large a growth in the fall and is in danger of throwing up culms, or becoming jointed, as it is called, pasturing, especially with sheep, may even prove beneficial. This is a condition, however, which seldom arises.

488. Enemies of Rye.—Rye may become infested with the same weeds that infest winter wheat. Chess, however, is less commonly found in rye, probably on account of the greater hardiness of the latter. (139) It has no specific insect pest, but may be attacked by those insects which feed upon all cereal crops indiscriminately, such as the chinch bug, army worm and grasshopper. The stored grain is

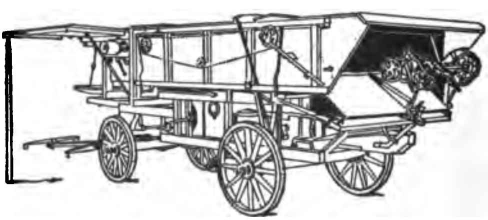
1 N. Y. (Geneva) Bul. 138, p. 629.

2 Tidsskr. Landbr. Planteavl., I, pp. 1-30; E. S. R. VII, 203.

also attacked freely by those insects which attack wheat and maize. (156) Rye is perhaps as freely injured by black stem rust and orange leaf rust as wheat, oats and barley. (146) It is also rarely attacked by a smut (*Urocystis occulta* (Wallr.) Rabh.). Treatment of seed with hot water at 127° F. is recommended. The greatest enemy of rye, however, is ergot, sometimes known as spurred or horned rye (*Claviceps purpurea* Tul.). Ergot is readily recognized by the very much enlarged and changed appearance of the grain caused by the growth of the fruiting spores. It is from these diseased grains that the ascospore stage develops the next year. Rye containing ergot should not be sown and land which has produced the diseased rye should not be sown to rye again for two or three years. It is desirable, in case the crop has been diseased, to put the land in some cultivated crop the succeeding year in order to prevent the growth of volunteer rye, which is very likely to be diseased and thus continue the trouble. Rye containing ergot should not be fed to domestic animals nor eaten by persons because of the serious effect which may follow from such use.

Ergot on spike of rye. (After Clinton.)

**489. Harvesting.** — Rye usually ripens about a week in advance of winter wheat. On account of the greater length of culm, heavy crops of rye are likely to tax the capacity of self-binding harvesters. Rye may be shocked as indicated for wheat. (161) But ordinarily it is not necessary to cap rye because the spikes lie so close together as to form a sufficient protection without capping. On account of the much higher price which can be obtained for straight rye straw as compared with tangled straw, threshing machines have been devised for keeping the straw straight during the operation, and some of the machines have a self-binding attachment by which the stray straw is bound again into bundles. Machines



Rye thresher with attachment for binding straight straw after it is threshed.

are made suitable for the use of individual farmers as well as the large machines intended for itinerant threshing.

490. **Use.**—The grain of rye is used for the production of flour, for food for domestic animals, and for the production of alcohol and alcoholic beverages. Rye flour is prepared in two forms: (1) fine rye flour, which has been thoroughly bolted according to modern processes of milling (176, 177), and (2) coarse rye flour, which corresponds to Graham flour in wheat. (174) Bread made from coarse rye flour has usually been esteemed more nutritious than that made from fine rye flour. Fine rye flour is less nutritious than bread from wheat flour. On the European continent where coarse rye bread is usually eaten it has been considered more nutritious than wheat bread. Digestion experiments, however, tend to show that fine white flour contains the greater net available energy. In America rye bread is in very small demand and mostly by those who have acquired a taste for it in European countries.

Rye, preferably ground, forms a satisfactory food for all classes of domestic animals, and may be fed as a substitute for maize whenever the price is such as to justify. Rye straw is used in the manufacture of paper, for a great variety of packing, including fruit trees, and for bedding for domestic animals. Rye straw is so highly prized for these uses that rye is largely raised in this country for the production of straw rather than for the production of grain. Were it not for the demand for the straw, the production of rye would probably rapidly decrease.

"The manufacture of straw is one of the most important industries of this Empire, giving thousands means of support. I believe it could be profitably introduced into Wisconsin, Minnesota, northern Michigan, the woods of Maine and hills of Vermont, New Hampshire and western Massachusetts. Straw, that once served only for fuel or fertilizing purposes, is put up by these people into the most useful, beautiful and fantastic forms. Plates, dishes, baskets, boxes, tables, trunks, fans, hats, caps, mats, etc., are made by the million and sent to all parts of the world. In a stretch of country containing six square miles, there are 10,000 persons employed in making articles of straw.

"Of the straws used, the best come from Tuscany. They are rye and wheat straws, and are known as the 'grano marzuolo,' or March grain. It is sown in March, very thick, to prevent the blades from growing too fast or strong. In June it has grown to a length of 18 or 20 inches and is ready for use. The rye and wheat is torn out by the roots, bound into small bundles, exposed to the sun but not to the rain, and is then laid aside for one or two years' seasoning. Before being worked, the bundles are spread out like fans, exposed three nights to the dew and three days to the sun; they are then turned to expose the other side two nights to the dew and three days to the sun. In this way, the straw that was green becomes a beautiful yellow or golden white. The ears and roots are now removed, and the stems are sorted into twelve to twenty sizes."[1]

491. **Rye as a Soiling Crop.**—Rye is especially acceptable to milch cows, when fed as a soiling crop the flow of milk being well maintained, and no bad results accrue from its use. The period during which it is available is comparatively brief, however, usually not more than two weeks in the latter part of April and fore part of May, varying somewhat with latitude and season. The period of maturity in which it makes a desirable soiling crop varies from just before heading until it is in full bloom. Prior to the earlier stage the yield is not sufficient to justify its use, and after the later stage it is not sufficiently palatable to be eaten readily. The Pennsylvania Station has shown that between the extremes noted, requiring twelve days, the yield of dry matter in the plant increased approximately from 1,200 to 2,800 pounds per acre.[2] In a system of soiling the hiatus between rye and oats and field peas (405) may be filled in with wheat and later with common red clover. At the Alabama Station four cuttings of rye made in October, November, January and February gave a total of eleven tons of green rye per acre.[3]

492. **By-Products.**—The by-products of rye are rye bran and distillers' grains. Rye bran has about the same feeding value as wheat bran. The distillers' grains are the by-products

[1] J. C. Monaghan: Germany's Straw Industry. Consular Reports, Vol. LVIII (1898), No. 216, p. 53.

[2] Penn. Rpt. 1893, p. 52.

[3] Ala. Bul. 16.

of the manufacture of alcohol and also contain varying proportions of rye and other cereal grains. (357) Usually the higher the proportion of rye used, the less the percentage of protein and fat and the lower the feeding value.

493. **Rye Crop of the World.**—The world's production of rye varied during 1898-1902 from 1,449 million (1901) to 1,678 million (1902), the average annual production being 1,560 million bushels. The following table shows the average annual production of rye for five years by continents in million bushels:

| | 1898-1902 |
|---|---|
| Europe | 1,471 |
| Asia | 58 |
| North America | 31 |
| Total | 1,560 |

Russia produced fifty-four per cent of the entire crop during this period; Russia and Austria-Hungary sixty-two per cent. Excepting the maize crop of the United States, Russia produces more rye than any other country of any one crop.

494. **Rye Crop of the United States.**—The reported acreage of rye in 1899 showed a decrease of 5.4 per cent since 1889, accompanied by a ten per cent decrease in production. While barley appears to be relatively increasing in acreage, rye appears to be decreasing. In 1880 the acreage of barley was about one million in excess of that of rye; in 1900 the acreage of barley was more than double that of rye, the latter having made comparatively slow progress since 1880. The average price per bushel during the ninety decade was fifty-two cents, a decrease of nine cents from the previous decade. The value per acre of rye in 1899 was $5.95, the least of any of our cereals, grain alone being considered. While the annual exportation of rye, seven million bushels for 1898-1902 inclusive, is small compared with wheat or maize, it is about one-fourth the total production. There is practically no importation.

495. **Center of Production.**—In 1850 the concentration of the rye crop in the North Atlantic division was greater than that of barley, eighty-three per cent of the entire crop coming from that region. The westward movement has not been so rapid as in the case of barley; the North Atlantic division furnished twenty-nine and the North Central division sixty-three per cent of the total production in 1900. The center of production in 1850 was somewhere west of the center of New York and Pennsylvania; in 1899 it had shifted westward into the State of Illinois. Fifty-three per cent of the crop of 1899 was furnished by four States: Wisconsin, Pennsylvania, New York and Michigan.

496. **Yield per Acre.**—The average annual yield per acre of rye during the decade 1893-1902 was approximately fifteen bushels, an increase of about three bushels over the previous decade. There is little variation in yield in the North Central and North Atlantic States; the South Atlantic States fall quite below the average. Twenty to twenty-five bushels per acre is considered a good yield. The legal weight per bushel is fifty-six pounds in Canada and all the States of the Union, except California, where it is fifty-four pounds.

497. **Commercial Grades.**—Only one class of rye is recognized, the following being the rules for grading this class by the Illinois Board of Railroad and Warehouse Commissioners:

"No. 1 rye.—Shall be sound, plump and well cleaned.

"No. 2 rye.—Shall be sound, reasonably clean and reasonably free from other grain.

"No. 3 rye.—Shall be reasonably sound, reasonably dry, free from must, and not good enough for No. 2.

"No. 4 rye.—All rye, damp, musty, or for any other cause unfit for No. 3."

498. **History.**—The cultivation of rye is not nearly so ancient as that of wheat and barley. It was unknown to the ancient Egyptians. The ancient Greeks did not know it. Its introduction into the Roman Empire was hardly earlier than the

Christian era. The origin of its cultivation is supposed to be northeastern Europe.

Within modern times rye was formerly a more important crop. Even as late as the middle of the nineteenth century rye was said to have formed the principal sustenance of at least one-third the population of Europe, barley taking its place in countries nearer the Mediterranean. It was annually sown with wheat, and is yet to a large extent mixed with wheat in grinding, and the resulting flour is called *meslin*. The mixture of maize and rye for bread was common in New England. Relatively, rye was formerly much more important in England and the United States.

## Practicums.

499. INFLUENCE OF SPECIFIC GRAVITY UPON GERMINATION. — Make up three solutions of sodium nitrate with a specific gravity of 1.20, 1.26 and 1.32, using a hydrometer to determine the specific gravity. Solutions may be placed in oatmeal dishes. Take preferably a sample of rye of rather low grade and divide into small, medium and large sized grains, either by hand or by means of sieves. (433) Then divide each sample into four groups according to specific gravity, by placing the sample in the solution of highest specific gravity; then put that which floats in the solution of next highest specific gravity, and so on. Grains can be conveniently removed from the solution by using a piece of wire gauze. Place fifty seeds of each of the twelve groups thus obtained in germinator at 70° F. and determine the number germinating in 24 hours . . .; 48 hours . . .; 72 hours . . .: 96 hours . . .; 120 hours . . . (475) Seeds may also be grown as in (433). Wheat and barley may also be treated in the same solutions, and many other agricultural seeds may be tested by varying the density of the solutions. A saturated solution of common salt and a saturated solution of ammonium nitrate made by boiling will upon cooling to 75° F. have a specific gravity of approximately 1.20 and 1.30 respectively. For further details, see N. Y. (Geneva) Bul. 256.

500. STUDY OF PLANT.—Examination under Nos. 1 to 8 preferably made in field: Nos. 9 to 16, in the laboratory.

1. Height of culm: average of ten culms to tip of upper beard . . .
2. Diameter below spike: average of ten culms . . .
3. Wall of culm (compared with wheat): thick; medium; thin.
4. Foliage (compared with wheat): scanty; medium; abundant.
5. Rust: leaves, per cent . . .; culms, per cent . . .
6. Ergot: per cent . . .
7. Spike: erect; leaning; nodding.

8. Length of spike: average of ten spikes from lower joint of rachis to tip of upper outer glume . . .
9. Number of grains per spikelet . . .
10. Number of grains per spike: average of ten spikes . . .
11. Weight: one hundred grains . . .
12. Size: length of ten grains . . .; width of ten grains . . .; thickness of ten grains . . .
13. Plumpness: plump; medium; shrunken.
14. Weight per bushel: obtained by weighing one pint.
15. Draw outer glume of rye and wheat.
16. Draw flowering glume of rye and wheat, using bearded glumes.

# XXIV.

## RICE.

### I. STRUCTURE AND VARIETIES.

501. **Relationships.**—Rice (*Oryza sativa* L.) belongs to the tribe *Oryzeae.* In some respects it is rather more closely related to maize and sorghum than to the other cereals. There are a number of species of the genus *Oryza* growing wild in the tropics of both hemispheres. To this tribe also belongs wild rice (*Zizania aquatica* L.), sometimes called Canada rice and sometimes referred to as "the reeds," the fruit furnishing food for the reed birds or bobolinks. The wild rice plant is an annual, grows usually from five to eight feet in length above water, and bears a cylindrical panicle one to two feet long. The flowering glume is bearded and encloses a slender cylindrical kernel varying in length from a half to almost an inch, and is of dark slate color when ripe. It grows somewhat extensively in marshy places throughout North America, as well as northeastern Asia, particularly around the region of the Great Lakes, where the Indians collected it in large quantities for food and even sowed it rather extensively. Wild rice furnishes a nutritious and an acceptable food. Although prolific, the tendency to shatter its seed upon ripening will probably prevent its general cultivation.[1]

Another species of wild rice (*Zizania miliacea* Mx.) is common in the Southern States, especially in the bayous of Louisiana. No use is made of the seeds, but it is said that two crops of good hay may be cut from it annually.

[1] For further account of wild rice see The Wild Rice Gatherers of the Upper Lakes. By Albert Ernest Jenks; extract from the 19th Ann. Rpt. of the Bureau of American Ethnology.

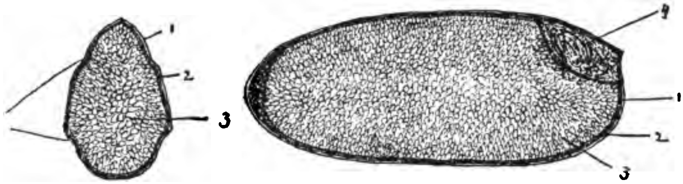
502. **The Plant.**—The culms of the rice plant vary in length from two to six feet, usually from four to five feet, depending upon soil, water and methods of culture. The Louisiana Station has found the straw as ordinarily harvested to vary from 1.6 to 2.3 pounds for each pound of rough rice.[1] Like the other so-called small grains, rice tillers freely; one seed sending up many culms when conditions are favorable. The spikelets are one-flowered, arranged on short pedicels so as to make a compact panicle in appearance somewhat intermediate between oats and barley. The outer glumes consist of two small scales or bristles, underneath which are two more minute rudimentary ones. The flowering glume is frequently awned. The flower of rice differs from all other cereals, having six stamens instead of three.

Stool of Honduras rice from a single seed. (After Bond.)

503. **The Grain.**—The fruit or caryopsis of rice is enveloped in the flowering glume and palea, which remain attached when threshed. When in this condition, rice is known as paddy. The flowering glume and palea are usually referred to as the husk or hulls, while the pericarp, testa and nucellus corresponding to the bran of wheat are referred to as the cuticle. The surface of the rice kernel is marked with four longitudinal depressions which give it a fluted appearance. The embryo is not embedded in the kernel but is so exposed that it is easily rubbed off in the process of milling. The cells of the aleurone layer are relatively small in one to two rows. Evidently these cells are removed by the polishing process. (526) The endo-

[1] La. Bul. 61, 2nd. ser., p. 392.

sperm is quite hard, and is glassy or translucent, with only here and there white or opaque spots. As in oats, the starch grains are compound. The rice grains usually vary from three-eighths




Longitudinal and cross section of rice kernel: 1, cuticle; 2, aleurone layer; 3, endosperm: 4, embryo; unnumbered lines show longitudinal depression in kernel. (After Dodson.)

to two-fifths of an inch in length. The weight of 100 grains may vary from two to three grams, or from 15,000 to 17,000 grains per pound.

504. **Composition.** — The following table gives the average of ten American analyses of clean rice, and one analysis each of rough rice and rice straw:

| | Clean rice | Rough rice | Rice straw |
|---|---|---|---|
| Water | 12.4 | 11.0 | 9.0 |
| Ash | 0.4 | 5.4 | 23.0 |
| Protein (N x 6.25) | 7.4 | 7.4 | 4.7 |
| Crude fiber | 0.2 | 9.3 | 32.3 |
| Nitrogen-free extract | 79.2 | 64.3 | 32.1 |
| Fat | 0.4 | 2.6 | 1.9 |

Clean rice is characterized by high percentage of starch and a correspondingly low percentage of other substances, especially crude fiber. Over ninety per cent of the dry matter of rice is nitrogen-free extract, almost exclusively starch. As a source of easily digestible carbohydrates, rice is without a peer among the cereals, and has few equals among food products.

505. **Varieties.**—There are five types of rice, among which are lowland rice and upland rice. These have sometimes been

considered distinct species, but they are probably only cultivated forms. As might be expected from a plant so widely and anciently cultivated as rice, there are a large number of varieties. In America, however, the varieties have been comparatively few. In the South Atlantic States the varieties chiefly used have been white rice, valued for its early maturity, and two varieties of gold seed rice, so called on account of their golden yellow hulls, differing from each other in the size of the grain, both of which are highly esteemed both because of their quality and the large yield of grain. In the South Central States there are three types of rice recognized, based upon the original source of the seed, viz., Honduras, Japan and Carolina rice. The Honduras rice is the type that has usually been raised, although Japan rice is now raised in large quantities. The grains of the latter are smaller, being shorter but relatively thicker than Honduras rice, and have a thinner hull. Japan rice also tillers more, fifty to eighty seed-bearing culms being not uncommon.[1]

Red rice is distinguished by the color of the grains, which may vary from very light to dark red, and the color may occur only in the seed coat or throughout the endosperm. This variety, practically wild, is sometimes considered a distinct species, and at least a distinct strain, is a strong and hardier grower than white rice, and will ripen its seed under more diverse conditions. Whenever it gets a foothold, therefore, it rapidly supplants the white rice. Since red rice materially lowers the grade, it causes rice planters great loss and becomes the worst weed that they have to combat.

## II. CLIMATE AND SOILS.

**506. Climate.**—Rice is a tropical or semitropical plant, and attains its best development in a moist, insular climate. In America rice is not raised north of the southern boundary of Virginia, Kentucky, Missouri and Kansas; and very little of it

[1] O. E. S. Bul. 131, p. 20.

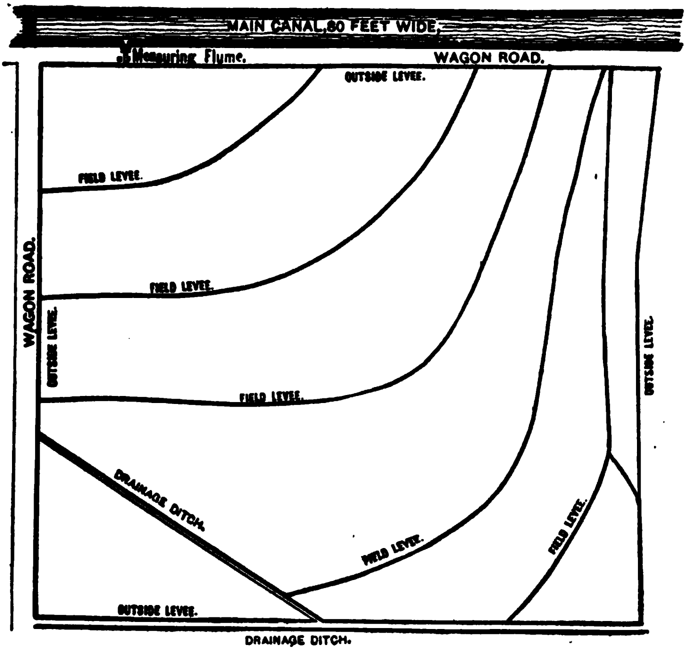
north of the southern boundary of Tennessee. Its climatic range is similar to that of cotton, being between 45° N. to 38° S. Lat. in the Eastern, and from 36° N. to 38° S. Lat. in the Western Hemisphere. Certain varieties of upland rice are said to be adapted to a somewhat wider climatic range. While upland rice may be raised by methods not dissimilar to that of oat culture, it is neither so productive nor of so good a quality as when raised by irrigation, the method most commonly practiced.

07. **Soil.**—The principal considerations concerning soil for rice are the ability to irrigate it, to drain it promptly, and to become solid with sufficient rapidity after the water has been removed for the passage of animals and machinery. Different degrees of fertility, however, are recognized, and soils of a clay nature have been found better than those of a sandy or peaty character; although here, as with other crops, a loamy soil with a fair degree of organic matter is desirable. The principal areas in the United States devoted to rice are: (1) the delta land and inland marshes of the South Atlantic States, (2) the alluvial lands along the Mississippi River, and (3) the prairie soil of southwestern Louisiana and southeastern Texas. The practices prevailing in the third area are radically different, both because the topography makes possible larger fields and because the solid subsoil allows the use of self-binding harvesters for gathering the crop. Upland rice may be grown upon any soil that will grow maize or cotton, and the method of culture is not materially different from that of oats or other spring sown grain.

508. **Rotation.**—A rotation of crops is seldom practiced on the rice plantation, although it is recognized that a rotation would increase the yield of rice per acre; but it would reduce the area grown. One very important reason for a rotation of crops is to free the land of noxious weeds; and planters are being forced to adopt a rotation for this purpose, which consists

of interjecting some other crop about once in four years, preferably a cultivated crop, such as maize, or merely permitting the plantation to grow up to dry land weeds.

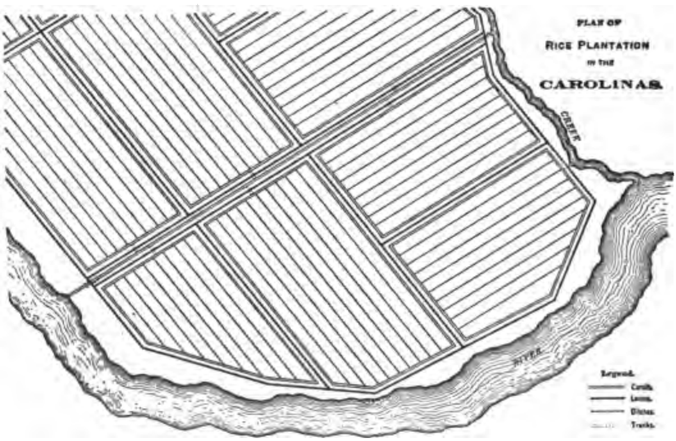
509. **Fertilizers.**—Many kinds of fertilizing material are commonly employed in oriental countries; in the United States




Plat of rice field in Raywood plantation showing method of irrigation in southwestern Louisiana and southeastern Texas. The different tracts are on different levels. Water enters at measuring flume, floods first tract, passes over field levee, floods second tract, and so on until the whole field is flooded. Water is removed through drainage ditch by opening field levees. On this plantation the water in the main canal shown in illustration has been raised a total of sixty-five feet by means of three pumping stations. At the initial station the canal is 150 feet wide. (After Bond.)

the land is seldom manured for rice. The irrigation of the land presents problems concerning nitrification and supply of fertilizing constituents from the water that have not been fully

worked out. Usually the water has an abundance of potash, a partial supply of nitrogen for the crop requirement, and scarcely any phosphoric acid. The Louisiana Station suggests the possibility of applying nitrogen and phosphorus in high grade commercial fertilizers in small quantities continuously to the water at the flood gates. Stable manure can be used judiciously upon places where surface soil has been removed in leveling




Plat showing method of irrigating rice plantation in South Atlantic States. Heavy black lines represent levees about six feet high, thirty-five feet wide at bottom and twelve feet wide at top. Main canal reaches from river to creek between two levees. Double lines around each tract represent marginal canals or face ditches about three feet wide and deep, and single lines represent field ditches about fifty feet apart. Water enters and leaves each tract through the same flume by means of a box, called a trunk, so arranged that it can be set to allow the water to enter at high tide or can be set to allow water to leave at low tide. (After Keeney.)

the land; but heavy applications are to be avoided upon good soil, lest it cause the rice to lodge. If the straw and hulls are returned to the land the fertilizing ingredients removed are comparatively small. Here, as elsewhere, the economy of fertilizers is a local question, and no specific rules can be given. (117)

510. **Laying Out the Plantation.**—In preparing a plantation for rice culture, the area must be laid off into fields and a levee

or dike thrown up around them. On at least one side of each field there must run a canal or sub-canal. These fields vary in shape and size according to the topography of the land and the ability to bring water to it. Usually the fields range in size from ten to forty acres. These fields are now subdivided into smaller areas, in order to get the water over the whole area with some uniformity. It is at this point that the system followed in the South Atlantic States differs radically from that of the South Central States. In the former the fields are subdivided by ditches placed parallel, usually about fifty feet apart, through which the water is conveyed to and from the land. In the South Central States the fields are divided into sub-fields or cuts, this being done by throwing up field or cut levees along the contour lines twelve to eighteen inches high. To flood the field, water is turned into the highest cut and conveyed from there to the next highest cut, and so on until the field has all been flooded. A drainage ditch at the long part of the field removes the water. The main features of the two systems are shown in the illustrations on pages 362 and 363.

It is important that each of the smallest units of land be as level as possible, so that the water can be kept at as uniform depth as may be over the whole area, since uniformity of depth of water is a prime factor in the growth and maturity of the crop. To obtain the best result, there should not be a variation of more than six inches in the depth of water.

511. **Water Supply.**—In the South Atlantic States the lands chiefly used for rice culture are the deltas near tidewater. Land is selected so that it may be flooded from the river at high tide and drained at low tide; and is sufficiently remote from the sea to be free from salt water. Rice may be grown in slightly brackish water, but salt water is disastrous. Usually the land is not less than fifteen nor more than thirty miles from the sea. A tide of four feet is sufficient and less is sometimes used. Where properly located, water in this region is ample. Along

the Mississippi River the water was formerly supplied from the river by putting a pipe through the levee, the land being highest next the river and the drainage being away from the stream. The water is now conveyed over the levee by means of a siphon, the former method being prohibited by law because the majority of disastrous breaks in the levees was attributed to them. In southwestern Louisiana and southeastern Texas not only are streams used for irrigation but advantage is taken of a stratum of water that underlies this territory at a depth of 125 to 200 feet. When tapped, this water rises near the surface, sometimes within twenty feet, and in a few instances flowing wells have been obtained. Whatever the source of water, it is pumped to raise it to the proper level. The individual planter may have his own pumping outfit or water may be furnished an extensive area from a single system, and the planter is charged a certain percentage (usually one-fifth) of the rice raised for water supplied, or a certain number of pounds of rough rice (usually two barrels, or 324 pounds).

Water for irrigation purposes should be uniform in temperature, not too cold, free from noxious weed seeds and injurious salts.

512. **Amount of Water Required.**—The amount of water required will vary with many conditions, including evaporation, seepage, drainage and the rainfall. Where abundant and obtained by gravity, larger quantities are likely to be used than where it is pumped. The Louisiana Station says that in that State each acre of rice is assumed to receive the equivalent of one-half inch of water daily during ninety days; this is forty-five inches. Deducting twenty inches for rainfall leaves twenty-five inches to be supplied by irrigation.[1]

The Office of Experiment Stations has measured the water used at two plantations where water is obtained by pumping, with the following results:[2]

[1] La. Bul. 77, p. 382.

[2] O. E. S. Bul. 113, pp. 22-28.

| | Raywood canal | Abbott land |
|---|---|---|
| Area irrigated, acres | 38.0 | 37.4 |
| Depth of water received from canal, inches | 19.7 | 16.5 |
| Depth of rainfall, inches | 9.2 | 10.0 |
| Total depth of water received, inches | 28.9 | 26.5 |
| Evaporation, inches | 16.0 | 14.5 |
| Net depth of water received by the land, inches | 12.9 | 12.0 |

## III. CULTURAL METHODS.

513. **Preparation of Seed Bed.**—Two methods of preparing the soil are followed, known as dry culture and wet culture. In the former the land is plowed in the fall and winter, preferably soon after the former crop has been harvested. In wet culture, the land is flooded in the spring, plowed and seed sown and harrowed in the water, after which the water is withdrawn to permit the rice to germinate. Wet culture is commonly practiced upon the buckshot soil because of the difficulty of plowing it when it is dry. Plowing is usually shallow, sometimes not more than three inches deep. Machinery and the animals drawing it usually sink to the depth of the plowed land; thus deep plowing adds to the labor, especially in the prairie regions where modern harvesting machinery is used. Whatever the customary depth of plowing, it is considered dangerous to plow deeper because of the accumulation of alkali in the subsoil just below the plow line. It is said, however, that where such deeper plowing is done, the alkali may in a measure be washed out by flooding and draining immediately after plowing.

514. **Sowing.** — The date of sowing may vary from the middle of March to the middle of May. Where dry culture is practiced the sowing is earlier than with wet culture. On

the alluvial lands of the Mississippi River the seed is sown broadcast by hand, but on the prairie soils seeding with the ordinary grain drill (135) is preferred because of the saving of seed and uniformity of germination. (131) The rotary broadcast seeder, however, is frequently used. (412) In the South Atlantic States the land is laid off with a trenching hoe into small furrows two to three inches deep, three to five inches wide and twelve to fifteen inches apart. Into these drill rows the seed is deposited and covered lightly, or more rarely left uncovered, in which case the seeds are sometimes soaked in thick clay water to prevent seed from floating away. The rate of seeding varies from one to three bushels per acre of rough rice. In the South Atlantic States two and one-half to three bushels are customary, while in the South Central States one to two bushels are ordinarily used. In new fields or in fields not infested with red rice, if any such exist, great care should be taken to use seed that is absolutely free from it.

515. **Application of Water.**—When lack of moisture makes it necessary, the land is flooded immediately after seeding for a few days to sprout the seed, when the water is removed. The land is then left until the plants are well started. In the South Central States flooding usually occurs when plants are six to ten inches high, which is from one to two months after seeding. The water remains on the land continuously until the grains are in the milk, when it is removed for the crop to ripen, which requires about a week. The period of irrigation varies from two to three months, usually about seventy days. Flooding usually takes place in June and the water is removed in August. The depth of water used varies, particularly with the supply. A uniform covering of three to six inches is considered satisfactory, although six to twelve inches are recommended. The water is constantly renewed in order to keep it from becoming stagnant, particularly to prevent the growth of weeds which are more abundant in stagnant water. The method

of irrigation in the South Atlantic States is somewhat different and is about as follows: As soon as the seed is sown water is let on for four to six days until the grain has sprouted and then withdrawn. This is called "sprout water." After the ricc has two leaves, enough water is put on to completely cover the plant, then lowered to about six inches, where it is held for twenty or thirty days, after which it is removed and the field allowed to dry. This is called "stretch water" or "long point flow." The field now remains without irrigation until the plant begins to throw up its culms, the land in the meantime being cultivated two or three times. Water is then turned on and remains on continuously, although changed every week to avoid becoming stagnant, until it is removed for harvest. This last irrigation is known as the "harvest water" or "lay by flow."

516. **Drainage.** — The drainage is effected chiefly through open ditches, generally rather shallow, but the main ditches should be three feet deep in order to remove more effectively the alkali, which in rice lands, as elsewhere where irrigation is practiced, is apt to become troublesome. Rice is rather resistant to alkali, however, so much so that it is sometimes employed for the purpose of helping to rid the land of alkali for other crops. Tile drainage is the most effective method of removing the alkali, but is usually not resorted to on account of the expense and in some cases would not be feasible on account of filling with sediment.

517. **Cultivation.**—Where the rice has been sown broadcast or by means of a grain drill, no cultivation is practicable. The worst weeds, however, are often removed by passing through the field and pulling by hand. In the South Atlantic States, however, the land is cultivated by hoeing lightly, or, more rarely, by using a one-horse cultivator. This is usually done before the plants begin to joint, the water having been removed and the land allowed to dry for this purpose. (515)

## IV. ENEMIES.

**518. Weeds.**—Perhaps the most serious menace to rice culture is the growth of weeds. This is especially true where rice is grown without cultivation, and where the water comes from streams which abound in weed seeds and readily disseminate them.

Dodson gives the following list of weeds which have proven most menacing to the rice fields:[1]

(1) Red rice (*Oryza sativa* var. *rufipogon*).

(2) Large indigo, straight indigo, coffee weed, senna, long podded sesban (*Sesban macrocarpa* Muhl.).

(3) Curly indigo, sensitive joint vetch (*Aeschynomene virginica* (L.) B. S. P.).

(4) Tadpole grass, wiggle-tail, spear grass (*Rhynchospora corniculata* A. Gray).

(5) Bull grass (*Panicum agrostidiforme* Lam.).

(6) Smart weeds (*Polygonum*, especially *P. acre* H. B. K.).

(7) Turtle back (*Commelina virginica* L.).

(8) Alligator head (*Diodia teres* Walt. and *Diodia virginiana* L.).

(9) Bird's eye (*Scleria*—several species).

(10) Morning glory (*Ipomoea tamnifolia*).

(11) Water grass (*Paspalum fluitans* Kunth. and *P. virgatum*)

(12) Moss weeds.

By far the most important and most serious one of these weeds is red rice. (505) Few rice fields are free from it. By many planters red rice is believed to result from volunteer plants growing from seeds of the cultivated white rice. It seems, however, to be demonstrated that it is a distinct strain, and that red rice can be obtained only from the seed of red rice. The two types readily cross, and the results of the Louisiana Station indicate that the red rice has the greater influence where crossing takes place.[2]

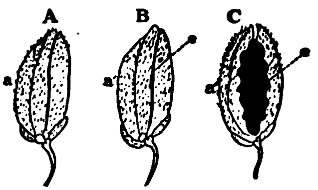
Next to red rice in importance is the large indigo weed, both because of its abundance and large size, the plant often growing to a height of fifteen feet, while the stems sometimes attain a diameter of two to three inches. Like the curly indigo, it is a leguminous plant.

The alluvial lands are especially liable to become infested with weeds, so that as a rule after two or three successive crops are raised, the soil must be devoted to a cultivated crop or allowed to grow up with weeds for one or two years. The weeds that are injurious to the rice plant are water weeds. If the land is drained, the field will grow up to dry land weeds and largely exterminate the water weeds, when the field can again be cultivated in rice. This is considered by some to be good practice, since the land retains its fertility and the finest crop of rice is the first crop

[1] La. Bul. 61, 2d ser., pp. 402-436.

[2] La. Bul. 50, 2d ser.

after such treatment. One of the reasons for flooding is to prevent the growth of weeds, but those which germinate quickly are enabled to keep even or ahead of the rice and thus escape injury from flooding. In some cases, where the weeds get ahead of the rice, especially those weeds (not grasses) which grow from the tip, the fields are mown, which checks the weeds, while the rice, but little injured, shoots ahead, when the field can be flooded and weeds killed. This is not effective for weeds of the grass family, because the habits of growth are the same as in the rice. Mowing stubble and burning it soon after rice has been harvested is a rather effective method of killing weeds; but the exposure of the bare soil to the rays of the sun and the lack of vegetation bring about physical, chemical and biological conditions that are undesirable. Mowing and burning late in the fall, after weeds have gone to seed, is, therefore, more commonly practiced, but is not so effective in destroying weeds, since the moist soil protects many from burning. This late burning is sometimes followed by early spring plowing to induce germination of weeds, when they may be destroyed by cultivation before seeding. This results in late seeding, which is objectionable. (514) In the alluvial lands the weeds are pulled by hand two or three times during the growth of the crop.



Three spikelets of rice; outer glumes shown at base. A, normal mature spikelet with healthy grain enclosed; B, grain affected with rice smut shown at e; C, grain more completely destroyed with rice smut shown at e. (After Anderson.)

519. Fungous Diseases.—The rice plant is sometimes attacked by a smut (*Tilletia corona* Scrib.), occurring on several grasses. It is very similar to the stinking smut on wheat. While not definitely proven, it is believed that the treatment recommended for stinking smut on wheat would be efficacious. (149) The smut has not been widely reported, but in some instances it has apparently done considerable damage. The kernel of the rice is filled with a mass of black spores, as in the case of wheat, but it is not usually abnormally large. The cause of blast or blight, a premature death of the plant or only the head, is not fully understood.

520. Insect Enemies.—The number of insects attacking rice are not many, nor are their injuries extensive or ordinarily serious. The principal one is the water weevil (*Lissorhoptrus simplex* Say). The adult is a small gray beetle, which makes its appearance in April and May and feeds upon the leaves of the young rice plant. The insects soon breed, and being semiaquatic in habit, the female lays its eggs among the roots of the plant. The eggs hatch in July and August into white, legless grubs, which feed upon the roots of the plant, where the principal damage is done, and which may be detected by the yellowish appearance of the plants, often in clumps. The presence of water seems necessary to the larvae; hence the removal of the water and drying the land at the proper time is recommended, although this practice is injurious to the rice.

The rice grub (*Chalepus trochypygus* Burm.) is a scarabaeid beetle, the larva of which feeds upon the roots of upland rice. Water kills it.

The rice stalk borer (*Chilo plejadellus* Treuck) is a crambid moth, the larva of which bores into the upper part of the stems, and in part, at least, is believed to cause what is known as "white blast." If it becomes serious, which is seldom, burning of stubble is recommended. The chinch bug (151) is sometimes injurious to rice fields, and the fall army worm (*Laphygma frugiperda* Sm. and Abb.), when numerous, may become injurious.

521. BIRDS.—In some sections, the rice bird, reed bird or bobolink (*Dolichonyx oryzivorus* L.) is one of the most serious obstacles to the culture of rice. It attacks the rice fields durng the ripening period, being especially injurious when rice is in the milk. The rice bird is particularly injurious in the South Atlantic States, where it is common to hire men and boys, called "bird minders," to scare away the birds, the common method being that of shooting off guns loaded with powder, but usually not with shot, since the latter injures the rice.

The English sparrow (*Passer domesticus* L.) has become a serious pest in parts of Louisiana, both to the ripening grain and while it is in the shock. The best prevention for the latter is prompt threshing, and, where this is not practicable, stacking.

Many species of other birds occur in large numbers in the rice districts, drawn there by the abundance of palatable food, the most numerous of which are the various species of blackbirds. While these birds eat some rice, they gain most of their sustenance from the grain that has fallen to the stubble and from weed seeds; and are, therefore, believed to be beneficial rather than injurious.

# XXV.

## RICE.

### I. HARVESTING AND USE.

522. **Time of Harvesting.** — It requires from four to six months to mature a crop of rice. The date of harvesting in the United States varies usually from August to October, the early seeding and early harvest being preferred. The price realized generally is greater on account of lack of competition from foreign rice. The stage of maturity is probably more important with rice than with any other cereal crop, because of its marked tendency to shatter, and because of the process of milling, which requires grains which are not easily broken. Uniformity of ripeness is also essential; hence the desirability of having all portions of the field covered with as uniform depth of water as practicable. To get the best results, it is usually considered desirable to harvest when the grain is in the stiff dough and the straw somewhat green.

523. **Method of Harvesting.**—In the South Atlantic States and along the Mississippi River the sickle is still used, although not exclusively. In this case the sheaves are laid upon the stubble to partially dry when they are bound. In some cases the bundles are put into the shock, where they remain until drawn to the thresher; while in other cases they are drawn from the field and placed in stacks, or in still other cases the grain is stacked loose. Heating in either shock or stack is liable to take place.

"A rough method of measuring the temperature of the rick is by inserting a stake into the mass at either end. The stakes are examined daily by being drawn out suddenly, and if the inner point is found to be too hot to hold in the hand, the

rick must be pulled down, aired and built afresh; but if the stake is not too hot to hold, the rick must be left undisturbed."[1]

In the prairie regions the self-binding harvester is used. (164) Slow curing in the shade gives best milling rice. Shocks should be placed upon dry ground lengthwise east and west, and caps should be put on with heads towards the north in order to avoid the sun as far as may be.[2] (161)

524. **Threshing.**—Rice is now universally threshed in the United States with the ordinary threshing machine. The itinerant machine (167) is used in the South Central States, but in the South Atlantic States stationary threshing machines placed under cover are employed, when they are referred to as threshing mills. Some care is required to adjust the machine so as not to break the grains.

525. **Use.**—The chief use of rice is for human food. It is estimated to enter into the dietary of more than one-half the population of the world, and is said to form more than fifty per cent of the subsistence of the people in some parts of Asia. In China it is used largely in connection with the fish raised so abundantly in their numerous waterways, and also with the soja bean (*Glycine hispida* Maxim.), which, on account of the high per cent of protein and fat in this bean, makes a diet resembling closely one made of meat, potatoes, bread and butter. Rice is usually eaten whole or in soups; it is seldom made into any form of bread or pastry, for which it is not well adapted, on account of its low percentage of gluten. It is sometimes, however, mixed with wheat flour. Rice is largely used for the manufacture of starch, and its lower grades are also used in the production of malt and alcoholic liquors. (465) The lower grades are so extensively used for this purpose as to be known to the trade as brewers' rice.

[1] U. S. Dept. of Agr., Div. of Stat. Misc. Ser. 6, p. 23.

[2] U. S. Dept. of Agr., Div. of Bot. Bul. 22, p. 29.

Rice straw is not highly prized as food for domestic animals on account of its lack of palatability, nor for bedding because of its coarseness. It is valued as manure for rice and other lands; the straw, together with roots and stubble, containing much the larger proportion of the ash ingredients of the plant. The so-called "rice straw" used for making hats and other articles is not rice straw but that of other cereals grown for that purpose. (490) The so-called "rice paper" of the Chinese is made from the pith of a tree native to the island of Formosa.[1]


Rice, variety Honduras, showing steps in the milling process: 1, rough rice, as it comes from the threshing machine, known as paddy; 2, same rice after it has been through the sheller, which removes husks or flowering glume and palea; 3, clean rice after it has been through either mortar and pounder or huller to remove cuticle and embryo, and through polisher to give it a highly finished surface. (After Bond.)

**526. Preparation for Use.**—The paddy or rough rice is prepared for use first by the removal of the husk or hull, and next by the removal of the cuticle or bran; the bran in this case being analogous to the bran, middlings and shorts of wheat. After the cuticle and embryo have been removed the kernels are polished in order to enhance their glossy appearance. This is believed in no way to improve the nutritive value but rather to decrease it; however, it greatly improves its commercial value. The following is a detailed account of the milling process:[2]

"The processes of milling rice are quite complicated. The paddy is first screened to remove trash and foreign particles. The hulls, or chaff, are removed by rapidly revolving 'milling stones' set about two-thirds of the length of a rice grain apart. The produce goes over horizontal screens and blowers, which separate the light

[1] U. S. Dept. of Agr., Div. of Stat. Misc. Ser. 6, p. 15.

[2] The Present Status of Rice Culture in the United States. By S. A. Knapp. U. S. Dept. of Agr., Div. of Bot. Bul. 32, pp. 34-35.

chaff and the whole and broken kernels. The grain is now of a mixed yellow and white color. To remove the outer skin the grain is put in huge mortars holding from 4 to 6 bushels each and pounded with pestles weighing 350 to 400 pounds. Strange to say, the heavy weight of the pestle breaks very little grain.

"When sufficiently decorticated, the contents of the mortars, consisting now of flour, fine chaff, and clean rice of a dull, filmy, creamy color, are removed to the flour screens, where the flour is sifted out. From thence the rice and fine chaff go to the fine-chaff fan, where the fine chaff is blown out and mixed with the other flour. The rice flour, as we call it, or more properly 'rice meal,' as our English neighbors call it, is very valuable as stock feed, being rich in carbohydrates as well as albuminoids.

"From the fine-chaff fan the rice goes to the cooling bins, rendered necessary by the heavy frictional process through which it has just passed. It is allowed to remain here for eight or nine hours, and then passes to the brush screens, whence the smallest rice and what little flour is left pass down one side and the larger rice down the other.

"The grain is now clean and ready for the last process—polishing. This is necessary to give the rice its pearly luster, and it makes all the difference imaginable in its appearance. The polishing is effected by friction against the rice of pieces of moose hide or sheepskin tanned and worked to a wonderful degree of softness, loosely tacked around a double cylinder of wood and wire gauze. From the polishers the rice goes to the separating screens, composed of different sizes of gauze, where it is divided into its appropriate grades. It is then barreled and is ready for market.

"In mills more recently erected the foregoing process has been modified by substituting the 'huller' for the mortar and pounder. The huller is a short, cast iron, horizontal tube with interior ribs and a funnel at one end to admit the rice. Within this tube revolves a shaft with ribs. These ribs are so adjusted that the revolution of the shaft creates the friction necessary to remove the cuticle. The rice passes out of the huller at the end opposite the funnel. It resembles externally a large sausage machine. It requires six hullers for each set of burs. The automatic sacker and weigher is used instead of barreling, sacks being preferred for shipping the cleaned rice. Sheepskins are used for polishing.

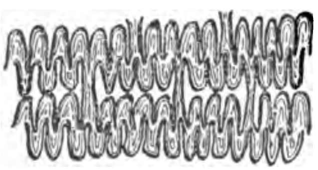
"With the above modifications of the milling processes considerable reduction has been made in the cost of the mill. Mills of a daily capacity of 60,000 pounds of cleaned rice can now be constructed at a total cost of $10,000 to $15,000."

Mills are now constructed suited to plantation use which combine all the operations in one machine, receiving the rough rice or paddy as it comes from the thresher and turning out clean rice ready for use. While the polish is not so high as in the more complicated processes, the product answers the requirement of rice eating.

In the preparation of rice for market it is important to have

the grain remain whole, since if broken its commercial value is reduced about one-half. These unbroken kernels are known as head rice. Great variations exist in different varieties and different grades of rice in the proportion of head rice to broken rice, as well as in the total amount of milled rice produced from a given amount of paddy. No accurate figures can be given of the proportion of head rice to broken rice, but the following illustrates what may be obtained from 100 pounds of a good sample of rough rice: head rice, thirty-seven; slightly broken, nineteen; very broken, six; polish, three; bran, fifteen; hulls and waste, twenty pounds. While as high as fifty per cent or more of head rice may be obtained in some cases, in others none is obtained. The product of American mills is about as follows: clean rice, sixty; polish, four; bran, seventeen; and hulls and waste, nineteen per cent.[1]

527. **By-Products.**—The by-products of rice consist of hulls, bran and polish. The bran is properly composed of the cuticle (503) and the embryo, with a small mixture of hulls which it is not possible to prevent in the milling process. In practice, a considerable quantity of hulls is mixed with the bran. This mixture, sometimes containing as high as seventy per cent of hulls, is usually referred to in commerce as rice bran, while when the bran is comparatively free from hull it is called rice meal. Both the bran and the polish are also more or less mixed with small particles of broken rice, called grits. Rice hulls are not only of no value as food for domestic animals, but apparently are injurious. They are consumed at the mills as fuel and sold for packing breakable articles and for similar uses. They are also ground and sold as husk meal or star bran. The



Characteristic ribbon-like rows of cells in rice hulls, highly magnified, which serve to identify the ground hulls when used as an adulterant. (After Street.)

[1] Twelfth Census of the United States, Bul. 201, p. 4.

Louisiana Station recommends a standard for rice bran of not more than ten per cent of hulls to prevent its adulteration with rice hulls. Assuming pure rice bran to contain ten per cent of crude fiber and pure hulls to contain forty per cent, the percentage of adulteration of bran with hulls may be calculated by subtracting ten from the per cent of crude fiber found upon analysis and multiplying by three and one-third.[1] The New Jersey Station calls attention to the characteristic cells of the hull arranged in several convoluted ribbon-like rows as an easy means of identifying ground hulls when mixed with other feed.[2] The following table gives recent analyses by the Louisiana Station:

| | Hulls | Pure bran or meal | Commercial bran [3] | Polish [4] |
|---|---|---|---|---|
| Water | 9.0 | 8.6 | 9.9 | 11.8 |
| Ash | 13.4 | 8.7 | 11.3 | 3.4 |
| Protein | 2.5 | 13.4 | 9.9 | 11.1 |
| Crude fiber | 41.9 | 9.5 | 14.7 | 3.8 |
| Nitrogen-free extract | 27.8 | 45.5 | 44.3 | 64.0 |
| Fat | 0.4 | 14.3 | 9.9 | 5.9 |

Rice bran, which is the chief by-product, is characterized by its high percentage of fat, which through fermentation frequently breaks up into fatty acids and glycerine, thus causing a rancid taste which makes the bran unpalatable to domestic animals. When fresh, however, the bran makes an acceptable food for all classes of domestic animals and it is especially useful for mixing with the more nitrogenous cottonseed meal. Polish has been successfully fed to cattle and pigs, but is more largely used for

[1] La. Bul. 77, p. 440.

[2] N. J. Rpt. 1902, p. 130.

[3] Containing sixteen per cent hulls and twenty-five per cent grits.

[4] Containing twenty-two per cent grits.

other purposes, as the manufacture of buttons and as a stuffing material in the manufacture of sausage.[1] The Louisiana Station has found the digestibility of commercial rice bran to be similar to that of wheat bran and polish to that of maize meal when fed to steers.

### II. PRODUCTION AND MARKETING.

528. **Production of Rice in the World.**—While it is estimated that rice enters more or less into the dietary of 800 millions of people, or half the people of the world, the production of rice is not known accurately. It is estimated that Asia produces 72,387 million pounds, Europe 1,507 million pounds, and North America 284 million pounds.[2] According to this estimate, which includes the principal rice producing countries, the production of rice is about one-half that of maize or wheat, somewhat less than that of oats, and somewhat more than that of barley. While rice has been estimated to constitute the principal food of at least one-third the human race, it is probable that other foods, such as sorghum seed and the seeds of legumes, enter largely into their dietary.

The countries of Central America produce rice somewhat extensively, Honduras being especially favored, while the countries of northern South America produce rice sparingly. Italy and Spain are the chief rice producing countries of Europe and Egypt of Africa. Rice is produced throughout the warmer parts of Asia, China, Japan and India being especially noted for its production and the high state of its cultivation.

529. **Production of Rice in the United States.**—Rice is a secondary crop in the United States, occupying, in 1899, about one-five-hundredth of the area in cereals. The production, however, has increased somewhat rapidly during the past decade on account of the development of the prairie regions

1 La. Bul. 77, p. 436.

2 Inter. Encyc. Vol. XIV, p. 1049.

of southwestern Louisiana and southeastern Texas. Marked changes have taken place in the production of rice in the South Atlantic States, due to changes in economic conditions, and to some extent to increased variations in the water supply, caused by the removal of forests from the headwaters of the streams. In 1899 sixty-one per cent of the crop of the United States was raised in Louisiana, seventeen per cent in South Carolina and twelve per cent in Hawaii. The only other States raising more than one per cent of the total production were Georgia, North Carolina and Texas. While Hawaii produces twelve per cent of the rice in the United States, this is not sufficient to supply the consumption of the islands. The Philippines also raise a considerable quantity of rice, but not sufficient for domestic consumption.

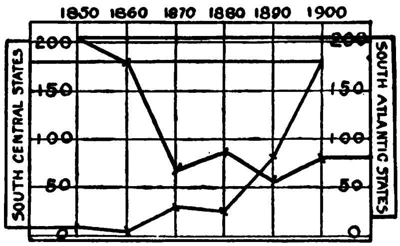


Chart showing production of rice in million pounds by decades in South Central and South Atlantic States.

530. **Yield per Acre.**—The average yield of rough rice per acre in the three census years, 1879, 1889, 1899, has been 746 pounds. In Hawaii the yield per acre in 1899 was reported as 3,663 pounds. In the Southern States a yield of ten to twelve barrels of 162 pounds each on irrigated land is considered satisfactory, while twenty barrels, and even thirty barrels, in exceptional cases, have been reported. The average price of rough rice in 1899 was three cents, and the value per acre was $22.46.

531. **Marketing.**—The weight of a bushel of paddy or rough rice is forty-five pounds. Paddy is, however, usually put up in barrels or sacks weighing 162 pounds, and commercial quotations are usually by the barrel, rather than by the bushel.

Quotations of milled rice are usually by the pound. The New Orleans Board of Trade recognizes the following grades: extra fancy, fancy head, choice head, prime head, good head, fair head, ordinary, screenings, common, inferior, No. 2. All grades between extra fancy and fair are for whole grains or head rice.

Grades between ordinary and inferior include broken grains; while No. 2 is composed of fine particles, which are sold principally to brewers. The wholesale price of rice of the highest grade is somewhat more than three times that of the lowest grade. Variations in grade of head rice depend principally upon the size of the kernel, the brilliancy of the polish and the pureness of the color.

The export of rice from the United States is insignificant, but the import is fully one-half as much as the domestic production. The principal sources are Japan, China, Germany and Great Britain.

### III. HISTORY.

532. **History.**—In the annual ceremony of sowing five kinds of seeds, instituted by the Chinese Emperor 2800 B. C., rice is considered the most important, since the Emperor must sow it himself, while the other four species may be sown by princes of the family.[1] (192) Rice was not known to the ancient Egyptians. It was introduced into Spain by the Saracens, and into Italy in the fifteenth century A. D. It was introduced into the Virginia Colony in 1647; but its cultivation cannot be said to have begun until 1694, when a small bag of rice seed was presented to the Governor of South Carolina by the captain of a trading vessel bound from Madagascar. The garden in Longitude Lane, Charleston, where the industry originated, so far as this country is concerned, is still pointed out.[2]

[1] Origin of Cultivated Plants, p. 385.

[2] Ramsey: History of South Carolina; U. S. Dept. of Agr., Div. of Stat. Misc. Ser. 6, p. 8.

## Practicum.

533. STUDY OF THE RICE PLANT.—The plant may be studied in the laboratory, or partly in field, as opportunity offers. Compare Honduras, Carolina and Japan varieties.

1. Height of culm: average of ten culms to tip of upper flowering glume . . .
2. Diameter of culms: average of ten culms just below raceme . . .
3. Vigor of plant: strong; medium; weak.
4. Wall of culm: thick; medium; thin.
5. Foliage: scanty; medium; abundant.
6. Length of raceme: average of ten racemes from base of lower spikelet to tip of upper flowering glume, not counting awn, if any . . .
7. Compactness of raceme: very open; open; medium; crowded.
8. Shattering: badly; medium; none.
9. Color: hull . . .; cuticle . . .; endosperm . . .
10. Density of endosperm: vitreous; mostly vitreous; partly vitreous; largely white.
11. Dimensions of grains: average of twenty-five: length . . .; width . . .; thickness . . .
12. Dimensions of kernel: average of twenty-five: length . . .; width . . .; thickness . . .
13. Weight: average of twenty-five: grains . . .; kernels . . .; per cent of hulls to grain . . .
14. Weight per bushel: obtained by weight of one pint . . .

534. COLLATERAL READING.

Rice: Its Cultivation, Production and Distribution in the United States and Foreign Countries. By Amory Austin. U. S. Dept. of Agr., Div. of Stat. Misc. Ser. 6, pp. 7-24.

The Present Status of Rice Culture in the United States. By S. A. Knapp. U. S. Dept. of Agr., Div. of Bot. Bul. 22 (1899), pp. 21-33.

Rice: Preparation, Cultivation, Flooding, Harvesting and Noxious Weeds in the Rice Fields. By Wm. C. Stubbs and W. R. Dodson. La. Bul. 61, 2d ser., pp. 385-392.

Irrigation of Rice in the United States. By Frank Bond and George H. Keeney. U. S. Dept. of Agr., Office of Expt. Sta. Bul. 113, pp. 14-20 and 60-68.

# XXVI.

## SORGHUM.

### I. STRUCTURE, COMPOSITION AND VARIETIES.

535. **Name.**—There is no common name which is applied generally to the different cultivated forms of *Andropogon sorghum vulgaris* Hackel, *A. sorghum* Brot., *Sorghum vulgare* Pers. The cultivated forms may be divided into three groups: (1) Those varieties whose juice has a high per cent of sugar which is used for making sirup and from which sugar is sometimes produced, known as sorghum (*Sorghum saccharatum* Pers.), sometimes probably incorrectly recognized as a separate species; (2) those varieties cultivated for their grain, known as Kafir corn, African millet, Indian millet, durra (spelled also dura, dhura, doura, dourra), milo maize, Jerusalem corn, Guiana corn, and Egyptian rice corn; (3) those varieties cultivated for the production of their spikes which are used for making brooms, known as broom corn.

The first form may be distinguished from the second and third forms by the quality of the juice, the first being known as sweet or saccharine sorghums and the second and third being known as nonsaccharine sorghums. In this book the word sorghum will be used to apply to all cultivated forms, and statements made are to be taken as applying to all unless otherwise stated.

536. **Relationships.**—Sorghum belongs to the same tribe (*Andropogoneae*) and to the same genus as Johnson grass (*Andropogon halepensis* Sibth.), which is believed by Hackel to be the original form of sorghum.[1]

[1] True Grasses, p. 59.

There are several species belonging to different genera of grasses which with sorghum often pass under the name of millet. Such are *Choetochloa italica*, formerly *Setaria italica, Panicum crus-galli, P. colonum, P. frumentaceum, P. miliaceum, Penisetum spicatum* (L.) R. & S. Several of these species have numerous cultivated varieties and numerous common names. Much confusion exists as to their botanical relationships and to the synonyms of the common names. The cultivation of some of these millets is very ancient, and the grain has been used extensively as human food. In the United States these plants are raised chiefly for hay. Canary grass (*Phalaris canariensis* L.), is raised for bird food, although sometimes in southern Europe for human consumption.

537. **The Plant.**—The roots of the sorghum plant are said to have strong feeding capacity, which enables the plant to withstand unfavorable environment. The Kansas Station found that the roots reach out laterally in all directions from two to six inches from the surface. The culms vary in height with variety, climate, season, soil and culture usually from four to eighteen feet, with greater variations in extreme cases. The culms, like those of maize, are solid. The leaves are abundant, rather thicker and more glossy than in maize. The upper leaf sheath sometimes extends around the lower portion of the head or spike; when in broom corn it is called the "boot."

538. **The Inflorescence.**—The inflorescence is in a more or less compact spike-like panicle, usually referred to as the head. The different types vary greatly in the form, size, compactness of the head; the usual variations in length being from ten to eighteen inches, except in broom corn, where the "brush" may be twenty-eight inches long.

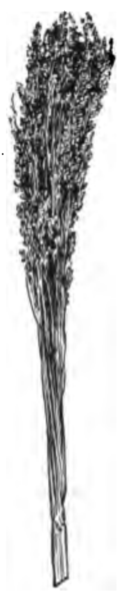
The spikelets are one-flowered, some being sessile and others on pedicels of varying length, usually one of each at each joint of the rachis.

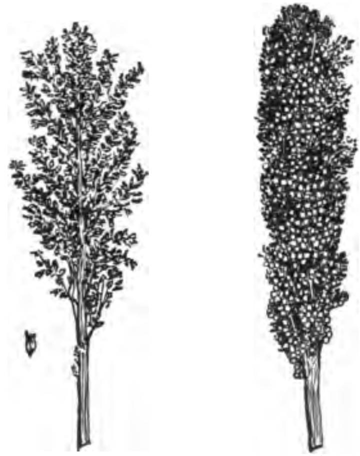
539. **The Grain.** — The grain varies from other cereals in being more or less round. The color of the grains is variable, white and red being the more common colors. The color resides in the seed coats. The size and shape of the grain vary largely with the type and variety. The grain of Kafir varieties is larger and rounder than sweet sorghum or broom corn varieties.

540. **Composition.**—Compared with the grain of maize, sorghum seed contains a somewhat smaller percentage of protein and about one-half the percentage of fat. Otherwise they are quite similar in composition. Sorghum fodder is distinctly lower in protein and higher in crude fiber than maize fodder. All varieties of sorghum contain some sugar, varying from two to twenty per cent of the juice, or from 1.2 to twelve per cent of the cane. Those varieties which contain sufficient sugar, say ten per cent, in juice, for the practical manufacture of sirup or sugar are called saccharine or sweet varieties, while other varieties are known as nonsaccharine varieties.

541. **Varieties.**—Large number of varieties of sweet sorghum have been tested in this country, particularly with reference to their value for the production of sirup and sugar. Among these varieties are two rather well marked types: the amber canes and the orange canes, the former of these being rather more early maturing than the latter. These are also recognized as desirable varieties for forage purposes. Early amber, extra early; Folger's, early; Colman, medium; and Collier, late, are recommended for this purpose as well as for the manufacture of sirup. Among the varieties grown for seed the principal ones are known as Kafir corn, of which three varieties are recognized: red Kafir, white Kafir and black hulled white Kafir (synonym African millet). In the red Kafir the seed is red or light brown, while in the white Kafir the seed is white. The hulls are gray or greenish white, while in the black hulled white Kafir the hulls are gray, brown or black. In both the white varieties the hulls are hairy and larger than in the red variety,

where the hulls (glumes) are small, thin and brown, covering less than half the grain. The seed of both white varieties is less astringent and more palatable than the red variety. At the Kansas Station the red and black hulled white varieties have given the largest yields; while at the Oklahoma Station the white varieties have given the best results. Up to the present time the red variety has been most generally grown,





A B C

A, Sorghum: type, standard broom corn. (After Hartley.) B, Sweet sorghum: variety, amber cane. (After Denton.) C, Kafir corn: variety, black hulled white. (After Georgeson.)

but the culture of the black hulled white variety is being rapidly extended. While the Kafir varieties have the widest adaptation and are most largely grown, durra (synonyms Indian millet, Egyptian corn), milo maize, Jerusalem corn and Egyptian rice corn are also grown, the latter two being especially adapted to higher altitudes and arid regions.

" These are very similar to Kafir-corn in many respects, and in growing, harvesting and feeding practically the same methods may be followed. The white milo maize grows a head very similar to Kafir-corn, is a heavy yielder of fodder, but

requires a full and favorable season for maturing, and is often damaged by frost on this account. The yellow milo maize, or 'Brown Dhura,' does not require so long a season, and is a heavy yielder of grain, the head hanging down on a short gooseneck, when ripe. The crooked heads, which hook and cling to everything they touch, are a great hindrance in handling. The seed also shells badly when ripe. Rice-corn and Jerusalem corn are very similar in their growth, the heads of both hanging down, ard annoying in the same way as those of the yellow milo maize. The seed of Jerusalem corn, being slightly flattened when ripe, can be distinguished from that of the rice-corn, which is round and also lighter in color. The two will mature in a short season and produce from twenty-five to fifty bushels of seed. They are adapted to the higher, cooler and drier counties of the western part of the state. They are very productive of seed, but the fodder yield is very light. In the eastern part of the state the English sparrow is a great pest where grain is raised. The seed is somewhat sweeter than the Kafir-corn grain, which they bother very little." [1]

Broom corn is divided into two types: the standard and the dwarf. Standard broom corn grows from ten to fifteen feet high, bearing a panicle of brush from eighteen to twenty-eight inches long; while the dwarf grows from four to six feet high and bears a brush of finer quality from ten to eighteen inches long, with occasionally strains that produce brush as long as two feet. The product of the dwarf variety is used for making whisk brooms and other brooms of small size; while that of the standard sort is used for making ordinary carpet brooms. The dwarf varieties have a larger amount of foliage, are better adapted to stand drouth, and for cultivation on sandy soils. Kafir varieties usually grow from four to seven feet in height; while sweet sorghum varieties usually range from eight to ten feet in height.

542. **Improvement of Varieties.**—The wide variations in the cultivated forms of sorghum suggest that the varieties might be easily improved or modified by selection, provided they are kept from crossing. Hartley has shown that broom corn and sorghum will readily cross and produce intermediate forms when grown in adjacent fields.[2] The different forms may become

1 Rpt. Kan. St. Bd. of Agr., March, 1900 p 64.

2 U. S. Dept. of Agr., Farmers' Bul. 174, p. 12.

injured by such crossing, thus making it desirable to exercise care with regard to the source of seed used for planting. The maintenance of a seed patch grown from seed selected from the best plants of the seed patch of the previous year is to be recommended here, as with other cereals. This is particularly true in the case of broom corn, inasmuch as there is considerable variation in the brush of different plants, crooked and thick centered brushes greatly reducing the value of the product. These forms are probably hereditary and, if so, could be eliminated in the course of time by selection, although it would doubtless take some time on account of the influence of crossing. Hartley suggests that it might be possible to produce a saccharine variety of broom corn, thus securing a variety that would produce both broom and sirup. For the production of grain, Kansas prefers long closely compact heads.

543. **Germination.**—The germinating power of sorghum is very likely to be low, and poor stands are very common because the grain, even though it has been thoroughly dried, is liable to absorb sufficient water in damp weather to produce fermentation. Grain intended for seed should, therefore, be left in the heads until planted. The heads may be either hung up separately or kept in loose piles in a dry, well-aired place. Testing the germination power is important and seed that is less than ninety per cent should not be used.

## II. CLIMATE AND SOIL.

544. **Climate.**—Sorghum is especially adapted to a climate that is both hot and dry.

"Perhaps the strongest recommendation of Kafir corn lies in the fact that it will produce a crop on less rain than is required for corn, and that it is not affected so disastrously by hot winds. It is, therefore, especially adapted to the semiarid West, where corn succeeds only one in five or six years because of hot winds and drought. It is owing chiefly to this quality that its culture has spread so rapidly in Kansas and Oklahoma. Hot winds are the main cause of the failure of the corn crop in this region, and they are never more destructive than when they happen to

come when the corn is tasseling. They cause the pollen to dry up, and the silk is not fertilized. Even with a sufficient rainfall, a few days of these withering blasts from the southwest, in tasseling time, may reduce the yield of corn fifty per cent. Kafir corn is not affected in the same way. Fertilization takes place more readily and the whole plant is better adapted to stand dry weather. The leaves are thicker and coarser than corn leaves, and do not dry out so readily; they are closer together and partly protect each other, and the plant is not so tall and, therefore, not so much exposed. When corn has once been stunted by drought or hot winds, it never recovers. Not so with Kafir corn. It may remain stationary and curled for days and even weeks, but when the hot winds cease and rain comes it will revive and, if not too late in the season, will still produce a crop of grain."[1]

It is necessary to distinguish between possible climatic range and the economic climatic range of sorghum. While sorghum can be grown in almost any climate in which maize can be grown, its economic climatic range does not extend north of the fortieth parallel.

545. **Soil.**—The soil requirements of sorghum are similar to those of maize, although the Kafir varieties are believed to succeed on land too poor to raise the latter. The plant also seems to be rather more resistant to alkali. For its best development, broom corn requires rich soil. Ordinarily it would not be wise to attempt to raise it on any but the best maize lands, although river bottoms are usually not desirable on account of the weeds. Dwarf broom corn succeeds best on dry, sandy soils, the brush having a tendency to grow coarse on the richer soils. The same principles apply in the use of fertilizers as in maize. (285-294)

546. **Rotation.**—Ordinarily sorghum takes the same place in the rotation as maize. It is a general experience that a crop following sorghum, particularly the Kafir varieties, is not so good as one following maize. The reason for this appears to be that the sorghum being more resistant to drouth continues to grow and thus exhaust the soil of its moisture, and possibly its plant food, when the maize would be prevented from doing so. The land thus breaks up hard and lumpy after the sorghum. As a

[1] U. S. Dept. of Agr., Farmers' Bul. 37, p. 5.

remedy for this, the Kansas Station recommends more thorough surface tillage of the sorghum. Inasmuch as broom corn is harvested soon after the flowers have set, the crop is not an exhaustive one. Broom corn is frequently raised continuously for many years on the same land without material diminution of the crop or injury to the land. Rotation of crops, however, is desirable on account of injury from insects and fungous diseases, particularly the latter.

### III. CULTURAL METHODS.

547. **Preparation of Seed Bed.**—The preparation of the seed bed is similar to that for maize except that greater care is imperative on account of the smaller seed and the slow early growth of the sorghum plant. For the first month after planting the growth of sorghum is much less rapid than that of maize, and the difficulty of keeping the land free of weeds is therefore greatly increased because of the difficulty of killing weeds without covering the plants.

548. **Time of Planting.**—In the sections in which it is grown the time required to mature a crop is rather less than that required for maize. During germination and early growth sorghum is very sensitive to cold, wet weather. It should not, therefore, be planted until the land has become thoroughly warm, usually from one to three weeks after the time for planting maize.

549. **Rate of Planting.**—Generally speaking, about twice the number of plants per acre should be raised of sorghum as of maize. That is to say, if at the rate of one grain every twelve inches in rows forty-two inches apart is the best rate in a given locality for maize for the production of grain, then one grain every six inches would be the best for the Kafir varieties of sorghum for the production of the seeds or grains. If one grain every six inches is the best for the production of maize fodder

or silage, then one grain every three inches would be the best for the production of sorghum fodder or silage. Since the Kafir varieties of sorghum do not grow as tall as maize, the rows may be closer together; three feet being often recommended where the rows of maize are usually planted three feet eight inches apart. Experiments, however, do not show that any greater yields of grain or roughage can be obtained by having the rows closer together, provided the same number of plants are raised per acre. Standard varieties of broom corn are planted at the rate of one plant every three inches in rows three feet six inches or three feet eight inches apart; and dwarf varieties are planted with plants two inches apart in rows three feet apart. The quality of the broom may be affected by the rate of planting; the thicker the planting, the finer the brush. Sorghum may be drilled or planted in hills; the former being the more common method. When the latter method is followed the hills are about eighteen inches apart in the rows. There are no experiments to show that the yield is greater in one case than in the other.

550. **Quantity of Seed.**—The quantity of seed per acre used in practice is quite variable because of the variety of purposes for which it is raised, different methods of handling, difference in size of seed and liability of low germination. Three to four pounds of good seed are sufficient to plant an acre of broom corn. Where Kafir varieties are grown for grain alone five to six pounds of seed are used and twice this amount where fodder is also wanted. Where sweet sorghum is grown for forage fifteen to thirty pounds planted in rows and cultivated produce a palatable product, and is usually the most satisfactory method of handling the crop. When sown broadcast or drilled, as in the case of wheat, to be mown and treated as hay, as high as 100 pounds of seed per acre are used. There is no evidence to show that this method produces greater yields, but it is preferred by some on account of the method of handling the crop, and because of its better keeping quality. Where the canes of sweet

sorghum are large they are apt to retain their juices, which when frozen ferment, and rapid deterioration of the fodder results. Where sweet sorghum is grown for seed for subsequent planting or for sirup two to three pounds per acre are sufficient.

551. **Method of Planting.**—Any form of maize planter may be used for planting sorghum by substituting special plates. In case special plates are not available the rotary disk plate of the maize planter may be filled with melted lead and bored out the proper size. The wheat drill can also be used as suggested for maize. (305)

"Perhaps the best and most practical is the ordinary grain-drill. As the rows should be thirty to thirty-six inches apart, the holes may be stopped by tacking a piece of pasteboard over all except those which will plant the rows the proper distance. On an eleven-hole drill, by stopping all but the outside holes and the middle one, the rows will be thirty inches apart; or by arranging a thirteen-hole drill the same way the rows will be thirty-six inches apart, providing the distance between the shoes is six inches. A marker may be put on the drill by bolting a two-by-four timber to the middle post of the frame and letting it project behind to fasten the marker to, and pull the other end by a rope or chain from the marker to the doubletree. Or a slat may be fastened to the frame of the drill and project out to the sides in front of the wheels, and a light chain or wire be fastened to the slat to drag in the wheel mark made the previous round, and so adjusted as to indicate the proper distance from the last row planted."[1]

Listing is frequently practiced, but more difficulty is experienced on account of the weeds and the slow growth of sorghum than in the case of maize. More injury also is experienced from flooding for the same reasons.

552. **Cultivation.**—The principles underlying the cultivation of sorghum and the tools used are the same as those for maize, the only difference being that greater vigilance must be exercised to prevent weeds from getting a start. (312) The land should be kept harrowed sufficiently before the sorghum comes up to prevent weeds getting a start, and after it is up may be harrowed with a weeder or light harrow as suggested for maize.

[1] Rpt. Kan. St. Bd. Agr., March, 1900, p. 56.

(299) While the plant is between three and eight inches in height it will stand harrowing better than maize.

553. ENEMIES OF SORGHUM.—Weeds are especially troublesome to sorghum on account of its slow early growth; but there are none that are not common to maize. The sorghum plant is attacked by maize rust (*Puccinia sorghi* Schw.) and also by smut (*Sphacelotheca sorghi* (L. K.) Clint.), which frequently does much damage to broom corn by producing its black smut spores in the seeds. It may be controlled by soaking the seed for fifteen minutes in hot water at 135° F.[1] or by the formalin treatment. The principal insect enemies are the chinch bug (151) and the plant louse. (333)

554. **Time of Harvesting.**—The stage of maturity depends upon the purpose for which it has been raised. When raised for grain the seeds are allowed to become thoroughly mature, which usually happens while the stem and leaves are still green. Plants may stand in the field in this condition for several weeks without material injury, although there will be some loss from the shattering of the seed. It is desirable, however, especially when use is made of the fodder, to cut and shock it as soon as the seeds have become thoroughly mature. With broom corn, brush of a light color is desired and is obtained by cutting as soon as may be after the pollen has fallen. The early cut brush is also said to be heavier and more durable. The milk stage is as late as it may be safely allowed to stand, although in California seed is allowed to ripen, greatly to the detriment of the brush, as much as a ton of seed per acre being obtained.[2]

555. **Method of Harvesting.**—No thoroughly satisfactory method of handling the crop has yet been devised, especially in humid regions where there is some difficulty in keeping both the stover and the grain. It may be cut and shocked after the manner of maize by any of the methods recommended for that crop. (342) In some cases the header has been used, which gathers only the heads and leaves, the stalks standing in the field. In other cases the heads are removed by hand with a

[1] Ill. Bul. 47; 57.

[2] U. S. Dept. of Agr., Farmers' Bul. 174, p. 17.

corn knife, thrown directly into the wagon box, and afterwards stored in narrow, well ventilated maize cribs.

556. **Threshing.**—The heads of the Kafir variety are frequently fed to cattle without threshing. In some cases the whole heads have been ground with fairly good results. For threshing Kafir varieties, the ordinary threshing machine is used, the concave being taken out and a blank concave or smooth board being put in its place in order not to break the grain. In some cases only the heads are fed into the machine, these having been removed in the field or subsequently cut off on a chopping block with a corn knife. In other cases merely the heads of the fodder are put into the machine and removed; while in still others the whole fodder is allowed to pass through the machine. The latter practice is not considered desirable on account of the readiness with which the shredded stover deteriorates.

557. METHOD OF HARVESTING BROOM CORN.—The brush of the dwarf varieties of broom corn are pulled by hand instead of being cut by knife. The brush is then laid in piles on the ground. On this account rainy weather during harvest is very disastrous to the crop. With the standard varieties of broom corn a method known as tabling is practiced. The rows of broom corn are bent over a distance of thirty inches from the ground toward each other but at an angle of 45° from the direction of the rows. The brush is now cut at a distance of six to eight inches from the base of the brush with a shoe knife; care being taken not completely to sever the upper leaf sheaf or "boot" when cutting the culm. The brush is then piled on each alternate table, thus leaving the intervening table over which the wagons may enter the fields to remove the brush.

558. PREPARING BROOM CORN FOR MARKET.—As rapidly as the brush is cut it is hauled to the cleaner, where the immature seeds are removed, the brush instead of passing through the teeth of the cylinder being carried in front of and at an angle with it in such a manner as not to injure the brush. Machines are made requiring twelve to fifteen men to operate, which will clean thirty to forty acres a day. There are itinerant machines, but it is more satisfactory for the grower to own his own machine because of the superior quality of brush which can be obtained by prompt handling. The cleaned brush is placed two to three inches deep on slats in open sheds in order to dry rapidly without exposure to rain or strong light. As soon as dry enough so that no moisture can be removed on twisting the stems, which will be in two to four weeks, the brush is piled in compacted tiers to prevent bleaching. When dry it is compressed with a machine similar to a hay baler into a bale, by overlapping the heads, thus leaving the stem end at each end of the bale. A bale

varies in weight from 300 to 400 pounds, averaging about 340 pounds. The brush is sorted at any convenient stage of the process. The most crooked brush can best be discarded in the field, while final sorting may be made just before baling. The production of broom corn is best engaged in by those who make it a specialty after having studied the business carefully in all its details.

### IV. USE AND PRODUCTION.

559. **Use.**—As a food for horses, cattle and swine, sorghum seed is not considered the equivalent of maize. It is less palatable and cannot successfully enter so exclusively or so continuously into their diet. On account of their more highly carbonaceous character large quantities of leguminous foods should be fed. The seeds are somewhat astringent, especially in the red Kafir variety, and when fed in large quantities cause constipation. As a food for poultry it is highly prized. As a food for calves raised on skim milk it is highly commended both because of its high proportion of carbonaceous material and because of its tendency to overcome scouring.[1] After a number of feeding trials, the Kansas Station concludes that the best way to feed the grain to fattening hogs is to place it unground into the feeding troughs and to pour over it sufficient water so that a small quantity will be left after the hogs have finished eating the grain. The purpose of the water is to lay the dust which, when the grain is fed dry, causes the hogs to cough severely. For cattle and horses the grain is usually ground, but whether grinding is best has not been experimentally determined. Large quantities of sorghum are raised for the fodder, handled after the manner ot maize fodder, or sown thicker and cut less mature as hay. It is also used for soiling, for which it is highly prized, for silage and for pasture. While large quantities of the nonsaccharine sorghum are used for this purpose, sweet sorghum is recommended as preferable. In the Southern States, where sorghum is sown as a hay crop, sometimes two and even three crops are harvested in one season; the plant, when cut

[1] Kan. Bul. 33, p. 40.

immature, possessing the ability to throw up new culms. Sweet sorghum is also used for the production of syrup, and formerly for the production of sugar, for which it is well adapted. The production of sugar from sugar cane and from sugar beets being more economical, the production of sugar from sorghum has been practically abandoned.

The seed of both Kafir corn and broom corn has been used to a limited extent in the production of flour. Although bread of an inferior quality may be made from it, it is chiefly used for the production of griddlecakes.

560. **Danger from Use.**—Many cases have been reported of animals dying suddenly from eating second growth or frosted sorghum. This was formerly believed to be due to bloating, and deaths may perhaps occur from this cause; but it has been pretty well demonstrated that deaths occur from violent poison which is found in sorghum of stunted growth. This poison is now believed to be due to prussic acid. Investigations of the Nebraska Station show that the prussic acid is not present as such but that it is liberated as a glucoside by an enzyme in the plant. It appears that this glucoside is always present in the plant, but the plant is harmless except under conditions which favor the action of the enzyme. The conditions which favor action of the enzyme are not fully understood; but it is believed that dry, clear weather, by arresting the normal development of the plant, is the chief cause of the formation of abnormal quantities of poison.[1]

561. SORGHUM SUGAR.—During the past twenty-five years the production of sugar from sorghum has been thoroughly studied, and several plants have been established in different States for its manufacture. While a considerable quantity of good sugar has been produced, most of the factories have been unsuccessful financially. Some of the difficulties have been:

1. A rather small yield of cane. The yield of cane has varied under normal conditions from about five to ten tons of clean cane per acre.

2. A low average percentage of sugar in the cane. The percentage of sugar is much more variable than in sugar cane or beets. The other solids are higher,

[1] Neb. Bul. 77.

thus making the percentage of available sugar still less. The total per cent of sugar in the juice of sorghum manufactured commercially has probably been considerably under ten per cent.

3. The rapid deterioration of the sugar in the sorghum from unknown causes, usually considered climatic, or from improper handling. Sugar cane may lie some weeks before it is used; beets may be stored for months; sorghum must be used at once.

4. Imperfect methods of extracting the juice.

5. Improper treatment of the extracted juice.

All these difficulties must be overcome before the manufacture of sorghum sugar can be a success. In the nature of the case the first three items are the most serious.

Manifestly, continued experiment may find some localities especially adapted to the production of high yield. The Delaware Station reports yields of cane varying from ten to twenty-five tons per acre, with available sugar varying from 2,700 to 6,600 pounds per acre, thus comparing favorably with the production of sugar from sugar cane or sugar beets. This result has been brought about partly by local adaptation, partly by cultural methods and partly by selecting during ten years seed from sorghum of high quality. Beginning with an amber cane in 1889 containing eleven per cent of sugar with a purity of sixty-five per cent, canes were produced in 1898 with more than twenty-one per cent of sugar having more than eighty-three per cent purity.

Some improvements in the removal of the leaves and heads from the canes and in the extraction of the juice have been effected, in the opinion of the Delaware Station. It is also proposed that the difficulty due to the perishable nature of the sorghum may be overcome by several small plants for cleaning the cane and extracting and concentrating the juice, with a central factory for the extraction of the sugar.

"To summarize, use seed from cane testing as high as possible in sugar, from 15-18 per cent, with juice purities in excess of 80 degrees. Select land which will produce fifty bushels or more of corn after repeated manuring with crimson clover, which crop may have been pastured down or plowed under, or cured as hay. Fertilize with muriate of potash broadcast at rate of 160 lbs. per acre. To this add 150 lbs. of nitrate of soda, provided some crop other than crimson clover has immediately preceded sorghum. Seed during the last fortnight in May, in rows 36 inches apart. Let each row consist of two lines of plants 4 inches apart, and in these lines let the plants stand at regular intervals of 6 inches. To each plant would then be given 108 square inches of soil surface. Cultivate as if for Indian corn. Prepare to begin milling during the last fortnight in September, provide cane for sixty days' work, to close November 15th. Such a field so planted and tilled should yield raw sugar in excess of 5,000 lbs. per acre."[1]

562. SORGHUM SIRUP.—Sweet sorghum is mainly grown for the production of sirup, although its production for this purpose has declined. Sorghum juice has a larger proportion of solids not sugar than maple juice or sugar cane juice and when

[1] Del. Bul. 51 (1901), p. 11.

these impurities are not removed they impart to the sirup an undesirable taste. As ordinarily manufactured, therefore, sorghum sirup is not as highly prized as maple or cane sirup, although good sirup can be made from sorghum by properly clarifying the juice. The process of manufacture is extremely simple or complex, depending upon the amount to be handled and the extent of the clarification. As rapidly as the canes are cut, which is when the seeds are in the dough stage, the heads and leaves are removed and the canes crushed between rollers to extract the juice. In the more simple processes the clarification is accomplished by skimming and decanting the liquid after allowing the sediment to settle.

These processes are assisted by neutralizing the natural acids present with lime, by boiling to coagulate organic substances, and by adding clay to weigh down the suspended materials. After clarification the liquid is condensed until it weighs about eleven and one-half pounds per gallon. On account of the rather large proportion of uncrystallizable sugar, there is comparatively little danger of granulation with sorghum sirup or "molasses." With a properly adjusted mill, the cane will yield sixty per cent of its weight of juice and yield as a maximum about twenty gallons of sirup per ton of clean cane.

563. **Sorghum Crop of the World.**—The seed of sorghum, under the name of millet or durra, enters into the dietary of a large proportion of the people of Africa and the drier and warmer portions of Asia. There are no statistics concerning its production. While it is not so palatable, it is not improbable that it is quite as important as is rice. The use of sorghum for sugar has been largely confined to America. It is somewhat but not extensively raised in Europe for fodder. Broom corn is raised both in Italy and France as well as in the United States.

564. **Sorghum Crop of the United States.**—Something less than 200,000 acres of sorghum seed were reported by the census of 1900 under the name of Kafir corn, almost all of which was raised in Kansas, Oklahoma, Texas and California. Much larger quantities, however, are raised for forage. The production of sorghum for forage is not listed separate from maize by the census, but of three millions so listed, more than half is grown in Kansas, Oklahoma and Texas, and one-third by Kansas, where both the sweet and nonsaccharine varieties are known to be extensively raised. In 1899 sweet sorghum was raised for sirup upon 447,000 farms, each farm raising on an average less than

an acre. The principal acreage is in the Southern States. None of the North Atlantic or Western States produces any considerable quantity. Kansas and Missouri are the principal producers among the North Central States. The yield per acre of cane was 6.5 tons and of sirup fifty-eight gallons. The total acreage of Kafir varieties in Kansas in 1899 was reported at 619,000 acres, of which 155,000 acres were raised for seed.

565. **Yield per Acre.**—As a grain crop, sorghum is more productive than maize in the semiarid districts. The Kansas Station reports an average yield for eleven years ending 1899 of forty-six bushels per acre of Kafir corn and thirty-five bushels per acre of maize. Their highest yield in any one year was Kafir corn ninety-eight bushels and maize seventy-eight bushels. In the semiarid districts west of the Kansas Station it is believed that the relative difference in yield is still greater. The average yield of broom corn in 1889 was 509 pounds of brush per acre, averaging four cents per pound, which has been the average price of broom corn brush in Illinois for the twenty-five years ending 1901. One-third of a ton of standard brush or one-fifth of a ton of dwarf brush per acre is considered a satisfactory crop.

566. **History.**—Sorghum is probably indigenous to tropical Africa, whence it was introduced into Egypt in prehistoric times and from there into India and finally into China.[1] Sweet sorghum was introduced into the United States in 1845 and widely disseminated through the influence of Orange Judd. The Kafir varieties now generally grown for seed were introduced about 1885 by the United States Department of Agriculture. Their cultivation has been rapidly extended in the regions to which they are especially adapted. Broom corn has been cultivated in this country for more than 100 years. Brewer believes the use of sorghum for the production of broom origi-

[1] Origin of Cultivated Plants, p. 382.

nated in the North Atlantic States, it having been formerly extensively raised in New York State, particularly in the Mohawk Valley.[1]

567. COLLATERAL READING.

Kafir Corn. By C. C. Georgeson. U. S. Dept. of Agr., Farmers' Bul. 37.

Sorghum as a Forage Crop. By Thomas A. Williams. U. S. Dept. of Agr., Farmers' Bul. 50.

Broom Corn. By Charles P. Hartley. U. S. Dept. of Agr., Farmers' Bul. 174.

Pedigreed Sorghum as a Source of Cane Sugar. By A. T. Neale. Del. Col. Agr. Expt. Sta. Bul. 51, pp. 3-11.

Sorghum Sirup Manufacture. By A. A. Denton. U. S. Dept. of Agr., Farmers' Bul. 135.

[1] Tenth Census of the U. S., Vol. Agr., p. 510.

# XXVII.

## BUCKWHEAT.

568. **Name.**—Buckwheat obtains its name from its resemblance to the beechnut; the German for buckwheat (*buchweizen*), meaning beechwheat, having been corrupted in English into buckwheat. *Fagopyrum*, the name of the genus to which this plant belongs, means beechwheat. Buckwheat is not a cereal from a botanical point of view, but because its seed serves the purpose of cereals and enters into commerce as such it is customary to class it with the cereal crops.

569. **Relationships.**—This plant belongs to the buckwheat family (*Polygonaceae*), which includes the various species of sorrel and dock (*Rumex*), and of smartweed, knotweed, bindweed (*Polygonum*), all more or less troublesome weeds.

570. **The Plant.**—The roots of buckwheat are entirely different from those of the true cereals, consisting of one primary root and several branches. While the primary root extends directly downward and thus reaches into moist soil, its roots do not extend over large areas either laterally or vertically. The plant grows from two to four, under ordinary cultivation about three feet in height. It has a watery stem varying at the base from three-eighths to five-eighths inch in diameter. While green the color of the stem varies from green to red, which upon ripening becomes brown. The plant does not tiller or sucker, only one stem being produced from each seed. The stem is more or less branched, however, depending upon the thickness of seeding; the plant by this means adapting itself to its environment. The normal amount of branching under ordinary field culture may be seen in (581). The leaves are

alternate, triangular, about as long as broad, varying in both dimensions from two to four inches, borne upon a pedicel varying from nearly sessile to nearly four inches in length. At the point where the branches or leaves arise upon the stem the stipule is developed into a legging known as an ochrea. The growth of the stem is from the tip instead of from the base, as is the case in the grass family.

571. **The Flowers.**—The pinkish white flowers are borne in a flat-topped cluster in the axils of the leaves and at the end of the stem or branch. There are no petals, but the sepals of the calyx have the appearance of petals. The calyx remains attached upon threshing at the base of the ripened grain. There are eight stamens and one three-parted pistil. There are two form of flowers, one with long stamens and short styles and the other with short stamens and long styles. Each plant bears but one form and the plants bearing the two forms are about equally divided. The New Jersey Station has shown that the fertility of the soil does not influence the ratio of the two forms and that seed from either form produce plants with both forms in about equal numbers; although a slight tendency to follow the parent form was thought to be observed.[1] The crossing between the two unlike forms by insect visitation is believed to be secured by this arrangement.

Buckwheat flowers: variety, silver hull, one-half natural size; blossom on left, long stamen and short style form, natural size.

572. **The Grain.**—The grain of buckwheat is called an achene, and consists of a single seed enclosed in the pericarp. The pericarp in a mature grain is a thick, hard hull with a

[1] N. J. Rpt. 1900, p. 458; 1901, p. 445

smooth, somewhat shining surface. This hull is slightly inflated, easily removed, its triangular edges often splitting apart in stored grain. The testa is membraneous, light yellowish green in color; the embryo is curved and extends through the center, dividing the endosperm into two parts. The endosperm is comparatively soft and pure white in color. The embryo is relatively larger than in wheat.

573. **Physical Properties.**—The grain of buckwheat may be described as a triangular pyramid with a rounded or bluntly rounded base. The base of the kernel after the hull has been removed is more nearly flat. While a cross section of the grain is usually three-angled, it is occasionally four-angled and more rarely two-angled. The grains vary in length from three-sixteenths to three-eighths inch. The width of the three sides is about equal, usually one-eighth to three-sixteenths inch at its widest part. The hull, and hence the grain, varies in color from silver gray to reddish brown and black. The legal weight per bushel of buckwheat varies in different States from forty to fifty-six pounds. In New York, Pennsylvania, Michigan and Canada, where it is chiefly raised, the weight per bushel is forty-eight pounds.

574. **Composition.**—The following is the composition of buckwheat, buckwheat straw, buckwheat flour and its by-products:

| | Grain | Straw | Flour | Middlings | Hulls |
|---|---|---|---|---|---|
| No. of analyses | 8 | 3 | 4 | 6 | 3 |
| Water | 12.6 | 9.9 | 14.6 | 12.7 | 10.1 |
| Ash | 2.0 | 5.5 | 1.0 | 5.1 | 2.0 |
| Protein (N x 6.25) | 10.0 | 5.2 | 6.9 | 28.1 | 4.6 |
| Crude fiber | 8.7 | 43.0 | 0.3 | 4.2 | 44.7 |
| Nitrogen-free extract | 64.5 | 35.1 | 75.8 | 42.2 | 37.7 |
| Fat | 2.2 | 1.3 | 1.4 | 7.7 | 0.9 |

As compared with the grain of wheat, buckwheat contains a somewhat lower percentage of protein and a much higher

percentage of crude fiber. The chief difference in the flour of wheat and buckwheat is the much lower percentage of protein in the latter, there being only about two-thirds as much protein in buckwheat flour as in wheat flour. Buckwheat straw contains a somewhat higher percentage of protein and crude fiber and a correspondingly low percentage of nitrogen-free extract. Buckwheat middlings is distinguished for its high percentage of protein and fat.

575. **Species.**—Three cultivated species of buckwheat have been recognized, only the first two of which have with certainty been grown in this country: (1) common buckwheat (*Fagopyrum esculentum* Moench.), (2) Tartary buckwheat (*F. tartaricum* Gaertn.), and (3) notch-seeded buckwheat (*F. emarginatum* Meissn.). Tartary buckwheat grows more slender, its leaves are arrow-shaped, with shorter petioles than common buckwheat; its flowers are greenish or yellowish in racemes.[1] The hull of the grain is rough and its angles wavy. The grains are smaller than common buckwheat. It is cultivated in the cooler and more mountainous parts of Asia because it is hardier and will succeed where common buckwheat fails. It is cultivated in eastern Canada, Maine, and occasionally elsewhere. The grains of notch-seeded buckwheat differ from this and the common buckwheat by having the angles or edges of the hull extended into wide, rounded margins or wings, thus making the total width of the grain greater, although the kernel is no larger. The hull is not rough but smooth, as in the case of common buckwheat, which it otherwise resembles very closely. Since no wild species has been reported, it may be a cultivated form of the latter. It is reported as cultivated in northeastern India and China.

576. **Varieties.**—There are three types or principal varieties of common buckwheat raised in America: Japanese, silver hull,

1 L. H. Bailey: Cyclopedia of Horticulture, p. 570.

and common gray. The grain of the silver hull is smaller and plumper than the Japanese. In the latter variety there is a tendency for the angles or edges of the hull to extend into a wing, making the faces of the grain more concave. The plant is also stronger and somewhat larger, and its flowers less liable to blast from hot weather. Each of these varieties has given the largest yield of grain in single tests at different stations. At the Ontario Agricultural College the average yield of grain during seven years has been Japanese, twenty-one; silver hull, eighteen, and common gray, sixteen bushels; of straw, 2.9, 2.8 and 2.6 tons respectively.[1] At the North Dakota Station two introduced varieties, Russian No. 1 and Orenburg No. 6, gave the best results.[2] The Japanese is sometimes mixed with a smaller growing variety. It is thought that more blossoms develop and that the Japanese in shading the smaller variety prevents its flowers from blasting. The desirability of this practice has not been experimentally demonstrated.

577. **Climate.**—Buckwheat is adapted to a moist cool climate; and while it will germinate in very dry soil the yield is very easily affected by drouth and hot weather. It grows at a higher altitude and its center of production is farther north than any other cereal in America. Under favorable conditions it will mature a crop of seed in eight to ten weeks, thus making it the shortest season cereal crop.

578. **Soil.**—Buckwheat does best on a rather sandy well-drained soil. It is possible to mature buckwheat on poor soil, and it is frequently grown on soil that is both poor and badly tilled. While apparently the soil has less effect upon yield than climate and season, nevertheless buckwheat will respond to a good soil, and no unfavorable results will follow from a high state of fertility. As in the other small grains, the proportion

[1] Ont. Agr. Col. and Expt. Farms Rpt. 1902, p. 119.

[2] N. Dak. Rpt. 1900, p. 59.

of straw will be greater, but when lodging occurs, the consequences are more serious than with the true cereals, since the plant has no method of rising again. (378) Buckwheat responds to applications of cheap low-grade fertilizers more regularly than most crops. In Pennsylvania farmers who do not use fertilizers on any other crop buy it for buckwheat. The fact that these low-grade manures are usually low in nitrogen and potash, but fair in phosphoric acid, indicates that it is especially benefited by the last.

579. **Rotation.**—Rotation is seldom practiced because of the place buckwheat holds in the farm management, being frequently resorted to as a substitute for meadow or maize that has failed. Other things equal, it is placed upon the poorest soil or upon that in the lowest state of productivity for cropping. The crop it follows is perhaps less important than the crop which follows it. It is often held that the succeeding crop of maize or oats is reduced because of its growth. Buckwheat leaves the soil in a remarkably mellow or ashy condition, which in the case of light soils is objectionable, but in the case of heavy soils is desirable, especially as preparation for potatoes particularly, on account of the smoothness of the tubers when the latter follow buckwheat. The following rotation is sometimes practiced: potatoes, one year; oats or wheat, one year, and medium red clover, one year. The first crop only of clover is harvested, when the land is immediately plowed and sown to buckwheat.

580. **Green Manuring.**—Buckwheat is sometimes used for green manuring. The ash constituents and the nitrogen are rather high for a nonleguminous plant. It will germinate in rather dry soil, grows rapidly and rots easily. Where these factors are important considerations the use of buckwheat for green manuring is indicated. It is possible by the use of buckwheat to incorporate organic matter into a soil that is almost too poor to grow any other crop.

**581. Preparation of Seed Bed.**—Since a great deal of buckwheat is sown because of the failure of some other crop or because the delay in farm work has prevented the preparation of the land in time for an earlier sown crop, the preparation of the seed bed usually takes place immediately before seeding. The land is usually plowed and prepared as for any other cereal. Early and thorough preparation of the seed bed, however, is advisable, as shown by the illustrations in this paragraph.

Buckwheat: variety, Japanese, showing influence of preparation of seed bed upon growth. Plat on which larger plant grew was cultivated during the spring, while in plat upon which smaller one grew the weeds were allowed to grow in the usual manner. Just before seeding, which was July 6, all plats were plowed and prepared in usual manner. Illustration shows plants at six weeks from seeding. From unpublished data of Cornell Station. (One-twelfth natural size.)

**582. Seeding.**—The date of seeding varies from May first to August first. The preferred time varies from the middle of June to the middle of July, depending upon locality. If sown too early, the flowers are liable to blast by the warm weather. The plant begins to blossom when quite small and continues until frost comes. Thus the plant has seeds in all

stages of maturity. When the earlier blossoms are blasted the later blossoms produce the seed. For this reason and because of the lateness of sowing, the crop is particularly liable to suffer from frost. The amount of seed used varies from two to five pecks, three to four pecks being common; depending principally upon the preparation of the seed bed. There is little trouble from foreign seed or from lack of germination. While the seed is usually sown broadcast by hand and harrowed in, the same reason exists for using the grain drill as in the case of wheat and other cereals. (131)

583. **Enemies.**—On account of its rapid germination and the quickness with which the plant shades the ground, as well as the time of year at which it is usually sown, buckwheat is little troubled with weeds. It is also especially free from insect attacks and fungous diseases. The principal causes of failure are the blasting of the flowers from hot weather and from drouth or flood.

584. **Harvesting.**—Buckwheat is usually harvested when the first seeds are fully mature, which is ordinarily in September. Buckwheat is a rather difficult crop to harvest. Much of it is still harvested with the cradle. Where the land will permit, probably the self-rake reaper is the most desirable implement. In this case it is not bound but is set up in shocks something after the manner of maize fodder. It may be cut with the self-binder, put in long shocks without caps and threshed as soon as dry. It is rarely stacked or put in the barn on account of the difficulty of getting the straw cured sufficiently to prevent heating. The grain is said to keep better, when carried over from one season to another, if put in two-bushel bags and piled loosely so as to admit of a good circulation of air, than when stored in bins. (168)

585. **Use.**—The principal use of buckwheat is for the production of flour from which the well-known buckwheat cakes are

made. There is also some sale for buckwheat groats, which is made by breaking the hull and separating the same from the kernels of the grain. The constant use of buckwheat is supposed to produce a feverish condition of the system which manifests itself in eruptions of the skin. Brewer suggests that inasmuch as plants of the buckwheat family are used for their medicinal properties, perhaps the cultivated species has some such property which affects its physiological value as a food. Buckwheat is highly prized as a poultry food, it being popularly supposed to stimulate the egg laying capacity of hens. There is no experimental evidence to support this belief. When ground, it makes a good food for swine. Under favorable conditions, 100 pounds of grain will produce sixty pounds of flour, twenty-four pounds of middlings or bran, and sixteen pounds of hulls. Buckwheat middlings is highly prized as a food for milch cows on account of its high percentage of protein and fat. Buckwheat hulls are of little value. They are sometimes mixed with the middlings, the mixture being known as buckwheat feed. As a food for domestic animals, the former is greatly to be preferred.

Buckwheat straw if protected from the weather is relished by stock. Where hay is so abundant that there is no occasion to feed straw, buckwheat straw has little feeding value; but if roughage is short it may be made to help out to good advantage. Used as bedding it does not last well, but it makes good bedding for cows, and because it is rich in minerals and rots so quickly it is desirable for manure. An old buckwheat straw stack or chaff pile is counted almost as good as manure. Some farmers report good results from using buckwheat as a green forage crop. It is highly prized for bees, buckwheat honey having a recognized place in the market.

586. **Production.**—Buckwheat is grown throughout the cooler portions of Asia, being extensively grown in Japan, and is rather sparingly grown in Europe, being less important there

than formerly. It is grown somewhat extensively in portions of Canada. In the United States the area devoted to this crop is one-sixth that of barley, about one-third that of rye and equal to the combined acreage of rice and sorghum grown for its seed. While a secondary crop, its place in the agriculture in the sections where it is grown is more important than the statistics would indicate. New York and Pennsylvania produced two-thirds, and, with Michigan, Wisconsin and Maine, produced more than four-fifths of the crop in 1899. The production has not changed materially in the past twenty-five years, although in 1860 the production was somewhat greater. In 1899 about 200,000 farms reported an average of about four acres each. There is a small importation of buckwheat from Canada; there is no export of either grain or flour.

587. **Yield per Acre.**—The harvested crop may vary in yield from five to fifty bushels, thirty bushels per acre being considered a rather large yield, and twenty to twenty-five bushels being considered satisfactory. The average yield in the United States in 1899 was, according to the census, fourteen bushels. The average yield for the ten years ending 1903, according to the estimates of the United States Department of Agriculture, was eighteen bushels per acre; the average December farm price per bushel for the same period was fifty-two cents.

588. **History.**—Although buckwheat is known to have been cultivated in China for 1,000 years, its cultivation is not believed to be very ancient. It was introduced into Europe in the Middle Ages, being unknown to the ancient Egyptians, Greeks and Romans. It was introduced early into the American Colonies, having been relatively much more important than at the present time. Formerly it was chiefly used as a substitute for wheat; now it is used as a luxury, although in many farm homes in Pennsylvania and New York buckwheat cakes constitute the principal bread food during the winter months. (170)

## Practicums.

589. DESCRIPTION OF BUCKWHEAT.—Give each student typical plants of two or more varieties:

1. Height of stem . . .
2. Diameter of stem: at base . .
3. Seed clusters: number per plant . . .
4. Number of grains: number per seed cluster . . .; number per plant . .
5. Color of grain: light gray; medium gray; dark gray; brown; black.
6. Plumpness of grain: plump; medium; shrunken.
7. Width: average of twenty-five grains . . .
8. Length: average of twenty-five grains . . .
9. Weight: average of twenty-five grains . . .; average of twenty-five hulls . . .; per cent of hulls . . .
10. Volume weight: weight per bushel by weighing one pint.
11. Specific gravity: use picnometer. (203)

590. RELATION OF BUCKWHEAT TO SOIL MOISTURE.—Having selected a soil, determine the amount of water it will hold when completely saturated. Fill sixteen three-gallon jars with this soil and determine the percentage of moisture in the soil. Sow buckwheat in four jars with sufficient water to fully saturate the soil; to four jars add three-fourths this amount of water; to four jars add one-half this amount, and to four jars one-fourth this amount. By weighing the jars, maintain the amount of water in them as indicated. At the end of three, six and nine weeks remove the plants from one jar in each of the series; determine their fresh weight and the weight of water-free substance and add sufficient water to the remaining jars to make up for the water of the plants. When the plants have ripened, determine the weight of grain and straw in each of the remaining jars.

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